FIRST LESSONS

IN

PHYSIOLOGY

FOR

USE IN THE COMMON SCHOOLS.

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REVISED AND ENLARGED.

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PREFACE.

The propriety of teaching some of the sciences in our common schools is so well established as to require no further arguments. Nor does it seem necessary here to justify the claims of physiological science; educators, and the people generally, are agreed that a knowledge of "the machine which we run and which runs us" is of the utmost importance. The question now under discussion is, how much of Physiology can be taught in the upper grades of the common school without infringing upon the other studies?

To facilitate the solution of this problem, as well as to meet the wishes expressed on many sides to see the essentials of Elementary Physiology arranged after the manner of the author's "First Lessons in Physics," the present volume has been prepared. It comprises thirty-nine lessons on the structure and functions of the human body, the subject-matter being treated with reference to the wants of the young people in the classes alluded to.

PREFACE.

These lessons profess to present the amount of physiological science which should be taught in the common schools. They include the essentials of hygiene, which are treated in immediate connection with the function of the organ to which they refer. Many technical terms, and all "rules" of hygiene based on mere assumption or personal bias, together with a host of trivialities frequently met with in works of the kind, have been excluded. For while the teacher under favorable circumstances can easily go beyond the limits of the text, it is an objectionable feature in a school book if, after its purchase, pupils are obliged to skim, or omit, any part of it.

Portions of recently slain animals should be used for demonstration, and the young learner be constantly urged to observe for himself.

The present revised edition contains a new chapter — Lesson XL. — on Alcohol and its effects, Stimulants, Narcotics, etc., etc., which sufficiently meets the requirements recently made by several States of the Union to teach those topics in the common schools. In this Lesson, as well as throughout the work, the author has deemed it best to keep his text within the limits of understanding of the young people for whom the book is intended.

CONTENTS.

PHYSIOLOGY.

First Lessons in PHYSIOLOGY.

LESSON I.

ORGANIC AND INORGANIC MATTER—ANIMAL STRUCTURE.

From time immemorial all things around us have been looked upon as either living or lifeless. Living objects are plants and animals;—lifeless, such substances as mineral-coal, iron, sand, rocks, water or air. Although in the present advanced state of science it is often difficult to draw the line, yet that distinction is still maintained, because between

things like those last mentioned, and substances such as wood or flesh, the differences are very striking.

All so-called lifeless substances are comprised under the head of *inorganic* matter, while the vegetable and animal worlds form the *organic* matter.

The distinction between these two great classes of materials is based upon *form*, *coherence*, *growth*, *composition* and *derivation*.

Form.—The sharp angles and straight lines of a crystal, the nearly regular features of most fragments of rock, are characteristic. On the other hand, notice the general absence of straight outlines in living structures, the curved shape of leaves and flowers, the rounded forms of the higher animals, and particularly those of the human body. Distinguish between the fracture of a lump of mineral-coal and that of charcoal. It will be your impression that inorganic matter, generally speaking, assumes forms of a severer pattern.

Coherence.—Particles of sandstone cling together owing to cohesion, without having any other mutual relation. A fragment of sandstone truly represents the original rock of which it once formed a part, inasmuch as it possesses all the properties of the rock. The particles of a tree cohere likewise, but they are closely dependent upon one another. A piece of wood does not strictly represent the tree from which it came, because in different parts of the same tree the wood may have different properties. Hence, the coherence of organized matter greatly differs from that of substances of the inorganic world.

Growth.—If the growth of a crystal, or of an ordinary rock, could be plainly observed, it would be found to consist in a mere adding of particle after particle on the outside, without any interior development. Nor would it be found accompanied by decay, or repair, going on at the same time; whereas, plants and animals, during their growth, always decay in part—that is, while they are building up they also lose waste matter, only the building up is far greater in quantity than the waste. This is true, regardless of the manner in which a plant grows, whether, for example, like most of our trees, it grows by adding superficial layers or rings around the stem, or, like Indian corn, by developing from within. Animals grow by interior development. Carbonic acid gas and water-vapor are two products of animal waste. Plants and animals make up the organic world, or world of organisms, and all organisms differ in their manner of growth from objects belonging to the inorganic world.

Inorganic substances present a mere building up without corresponding development of all parts; while an organism develops throughout, and thereby attains gradually to a higher organization. The grain of corn generates the plant; the egg brings forth the bird; the infant develops into the full grown man. Nothing of the kind takes place in inorganic matter.

Composition.—Copper, gold and iron are examples of elemental bodies; on being subdivided repeatedly, each yields its like again. Water is an

example of a compound body; it is composed of, and may be resolved into, two elements: hydrogen and oxygen. Clay, another compound body, consists of three or four elements. All these substances are inorganic; and nearly all inorganic substances are less complex in composition than organic bodies, such as wood or flesh. They are also more stable; that is, they do not decompose so readily.

Derivation.—An organism is derived from a parent; inorganic matter is not. This is one of the most peculiar characteristics of organisms.

Organisms live, develop and die; inorganic bodies are not said to live, develop, or die.

The structure of a higher animal, required for the complete display of its capacities, may be represented thus:

1. An apparatus to convert food into a fluid which will develop and maintain the body, and to remove waste materials.

2. A system of vessels to convey this fluid to all parts of the body.

3. A muscle or heart, which, by contracting and relaxing, pumps the fluid into the vessels.

4. A mechanism for respiration, so as to purify the fluid by a fresh supply of oxygen.

5. Contractile cords or muscles to set the different parts of the body in motion.

6. A mass of nervous matter, with nervous fibres spreading over the body, to receive impressions from the outer world, and to convey manifestations of will, &c., to the various portions of the body.

LESSON II.

BONES — THE SKELETON.

1. Experiment.—**Expose a bone** to the action of intense heat. Its shape will be preserved, but it will no longer be strong and tough; it will not support as much weight as before. It has now lost its animal substance.

2. Experiment.—**Soak a bone** in dilute acid. Its shape will be retained, but its firmness is destroyed; it may now be bent without breaking. It has lost its mineral substance.

The composition of bones is a close union of animal and mineral substances. In the normal bone both substances exist in definite proportions. A deficiency in the mineral ingredients (chiefly lime), as is the case with bones in early life, causes the bones readily to bend; while an excess of lime, always found in the bones of old people, renders the bones brittle.

The structure of bones shows a net-work of small canals and layers of bone substance. Bones are less dense at their centers; many of them contain a fatty substance, called the marrow. Bones grow and constantly renew their particles.

The growth of bones.— Every bone of an adult was at one time a cartilage. It did not become hardened uniformly throughout its mass, but the process of ossification—that is, the deposition of mineral matter in the cartilage—took place first at particular points, called the *centers of ossification.* Thus the long bones of an infant contain at least three such centers or bony masses, one in the middle part of the bone (then as yet a cartilage), and one situated toward each end. In the adult these three osseous centers are united into one solid bone.

When the edges or ends of bones in their growth come to touch each other, they either form *joints* or articulations, in order to enjoy motion upon each other; or they grow firmly together, forming *sutures.* Sutures may be readily ascertained in the bones composing the skull.

The *skeleton* consists of all the bones in the human body, the total number of which is about two hundred and ten, excluding the teeth. Besides, there is found a firm, elastic tissue called *cartilage* or gristle, such as the outer ear or the lower part of the nose.

The skeleton forms the framework of the body. It is usually divided into three distinct portions: the *head*, the *trunk*, and the (upper and lower) *limbs* (Fig. 1). It contains three cavities; the uppermost is a hollow box of bone, the *skull* or cranium; this contains the brain, and has attached to it the jaws and the remaining bones of the head.

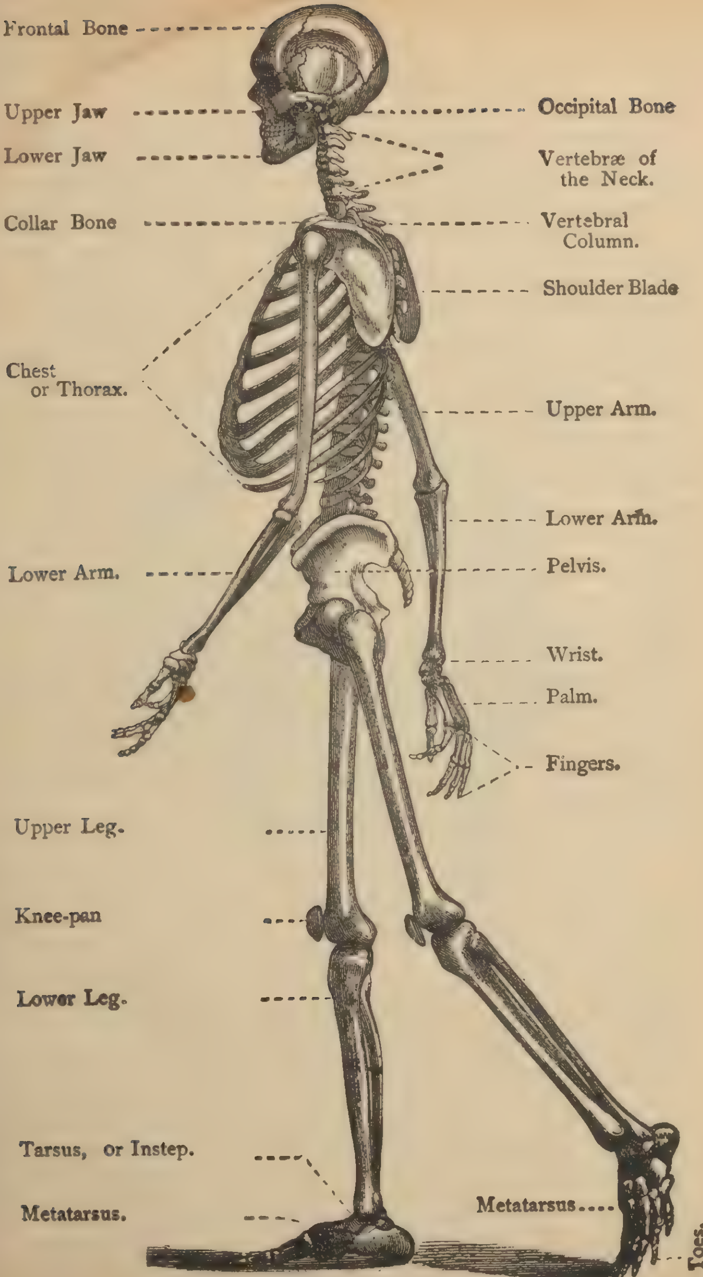


FIG. 1.—THE SKELETON

Below this a bony case or basket is seen, called the *chest* or *thorax*; and further down a bony basin, the *pelvis*. The chest and the pelvis, together with the backbone, form the trunk of the body. The arms, or upper extremities, are attached to the upper part of the chest by means of the *collar-bone* and the *shoulder-blade*. The legs, or lower extremities, are fastened to the lower part of the trunk.

Bones, like all organic structures, consist of *cells*, that is, of cellular tissue; the cells are more or less of a hexagonal form. Bones are renewed even more rapidly than any other portion of the body except the nails, the skin and the hair. The natural process by which broken bones are restored is remarkable. The immediate result of the injury is an effusion of blood around the broken parts. This is soon replaced by a watery fluid, which, after some time, thickens into a jelly-like mass. In a month or two this mass hardens, and slowly acquires the properties of bone; months after this the bones, if carefully treated, unite perfectly.

LESSON III.

THE HEAD—THE CEREBRO-SPINAL AXIS—THE TEETH.

The head (Fig. 2) consists of the bones of the skull, face and ear. Its principal parts are:

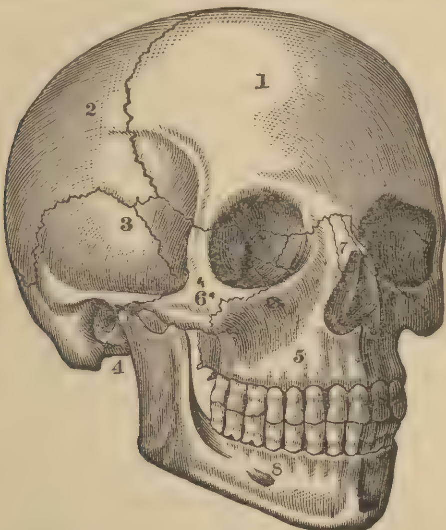


FIG. 2.

1. The *frontal bone.*

2. Two *side bones*, which form the uppermost part, and part of the right and left sides of the skull.

3. Two *temporal bones*, one on each side of the lower part of the frontal bone.

4. The *occipital bone*, extending down the neck.

5. The *upper jaw*. 6. Two *cheek bones*. 7. *Nose bone*.

8. The *lower jaw*, easily separable from the remaining parts of the head.

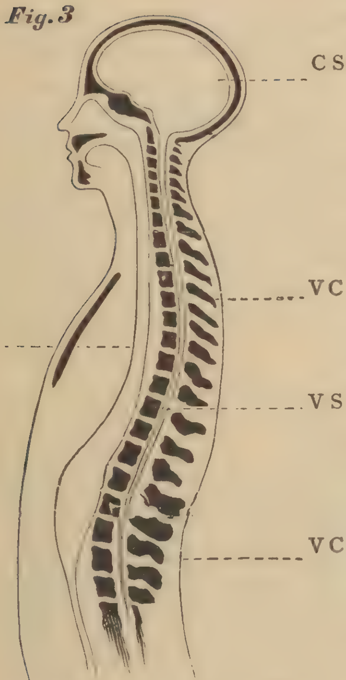
9. The *sphenoid bone*, forming the base of the skull (not visible in Fig. 2).

The upper jaw contains the upper row of teeth, the lower jaw, the lower. The lower portion of the nose consists of cartilage, which remains soft during life. The roof of the mouth is a thin but hard bone, forming part of the upper jaw.

The various bones of the head are firmly joined together, although they contain fissures and holes.

According to the preceding lesson, the skeleton is composed of head, trunk and limbs; and the trunk separable into chest or thorax, and pelvis. The young student will do well to observe that the head contains two distinct cavities: the cavity of the skull and that of the face, which are entirely separated from each other. The former contains a mass of nervous substance which is called the brain. This substance is continued down to the lower end of the pelvis, in the shape of a downward tapering cord, called the spinal cord. This cord together with the brain, pass under the name of *cerebro-spinal axis*. Thus, we discover that the skull together with the vertebral column (Fig. 3), form a tube very much expanded above and exceedingly narrow at its lower end; and that this tube is completely insulated, in the first place, by the bones of the skull, and secondly, by the vertebral bones, or *vertebræ*.

Fig. 3



VERTICAL SECTION OF THE HUMAN BODY.

A. L.—Alimentary canal.
V. C.—Vertical column.
C. S.—Cerebro-spinal axis.

The other cavity, that of the face, contains the mouth. The mouth is part of another tube, called the *alimentary canal*, which extends from the mouth through the entire length of the trunk in front of the vertebral column (Fig. 3). The cavity of the mouth may be considered the expanded upper end of the alimentary canal, just as the cavity of the skull forms the upper expanded end of the tube containing the spinal cord.

The cavity of the mouth contains two rows of teeth, one in the upper jaw, the other in the lower. Each tooth has a *crown*, *neck* and *fang* or *fangs*. The crown is the portion which projects beyond the gum. The neck is that portion immediately below the crown and on a level with the edges of the gum. The fang, or fangs if there be more than one, comprises all below the neck (Fig. 4).

The crown is covered with an exceedingly hard substance, called *enamel;* this is the hardest portion of a tooth, and the hardest substance in the human body. It forms a very thin layer, and serves as a protection to the principal constituent of all teeth, the *dentine* or ivory. This dentine is hollowed out into a cavity, which contains a very sensitive mass of nervous matter, the tooth-pulp (Fig. 4, *a*). Teeth are partially composed of bony matter; they differ from bones in possessing enamel and dentine, which bones have not. Teeth have no growth.

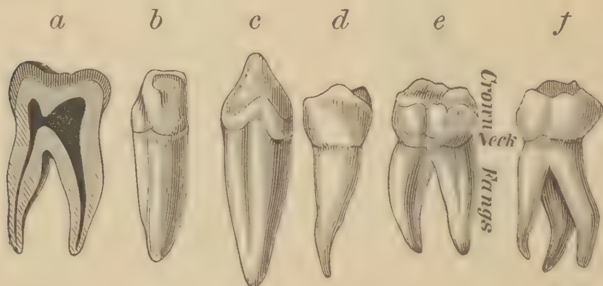


FIG. 4.

There are thirty-two teeth in number, sixteen in each jaw. The four front teeth in each jaw are adapted for cutting purposes, and therefore named *incisors* (*b*). On each side of them is a tooth with one cusp—that is, with a pointed crown (*c*). It is called the *eye-tooth*, or, because it resembles the long, tearing tusk of the dog, the *canine.* Next on either side is a tooth (*d*) with two cusps on the crown, larger than the preceding teeth, and called *bicuspid.* Adjacent to it are teeth with more than two cusps,

the *molars* or grinders (*e* and *f*), the broadest and most powerful of all. The crowns of the molars in the lower jaw have four or five cusps, while those in the upper have one cusp less.

In the early period of life, each jaw has ten temporary or milk teeth. At the age of six or eight the upper portions of these teeth fall out, or are 'shed,' while the fangs are absorbed. Then appears the second or permanent set of teeth, thirty-two in number. The following formula shows that the molars of the child are replaced by the bicuspids of the adult:

Formula of Arrangement and number of Teeth.

		Mo	Ca	In	Ca	Mo		
Temporary Teeth.	Upper,	2	1	4	1	2	= 10	=20
	Lower,	2	1	4	1	2	= 10	

		Mo	Bi	Ca	In	Ca	Bi	Mo		
Permanent Teeth.	Upper,	3	2	1	4	1	2	3	=16	=32
	Lower,	3	2	1	4	1	2	3	=16	

(Compare Lesson XXV.)

Familiar Facts.—Sudden changes of temperature, owing to very cold or very hot food or drink, are dangerous to the teeth, as they may cause the enamel to crack. Acids and metal toothpicks should be avoided. Teeth require cleansing with water and a soft brush, especially after meals. Any injury to the enamel is irreparable, and, as it causes the dentine beneath to decay, may involve the loss of the tooth.

Read "*Toothache,*" by S. Parsons Shaw. Lippincott, Philadelphia.

LESSON IV.—REVIEW.

LESSON I.—

1. Inorganic matter differs from organic, mainly in form, coherence, growth, composition and derivation.

2. An organism is an organized structure belonging either to the vegetable or animal kingdom.

3. Only organisms live, develop and die. The human body is the most perfect organism known.

4. The structure of a higher animal required for the complete display of its capacities may be represented thus: 1. An apparatus to convert food into a fluid which will develop and maintain the body, and to remove waste materials. 2. A system of vessels to convey this fluid to all parts of the body. 3. A muscle or heart, which, by contracting and relaxing, pumps the fluid into the vessels. 4. A mechanism for respiration, so as to purify the fluid by a fresh supply of oxygen. 5. Contractile cords or muscles, to set the different parts of the body in motion. 6. A mass of nervous matter, with nervous fibres spreading over the body, to receive impressions from the outer world, and to convey manifestations of will, &c., to the various parts of the body.

LESSON II.—

5. Bones consist of animal and mineral material. The former renders them tough and elastic; the latter gives them strength.

6. The animal substance in bones may be removed by heat; the mineral, by the action of acids.

7. Bones grow and constantly renew their particles.

8. The number of bones in the human body is about two hundred and ten.

9. Cartilages are firm, elastic tissues.

10. The skeleton may be divided into head, trunk and limbs.

11. Bones, like all organic structures, consist of cellular tissue.

LESSON III.—

12. The head consists of the bones of the skull and those of the face and ear.

13. The principal parts of the head are: 1. The frontal bone. 2. The side bones. 3. The occipital bone. 4. The temporal bones. 5. The upper jaw. 6. The cheek bones. 7. The nose bone. 8. The lower jaw. 9. The sphenoid bone.

14. The cerebro-spinal axis comprises the spinal cord and the brain.

15. A tooth is composed of a crown, a neck and one or more fangs.

16. The tooth-pulp is enclosed by dentine; the dentine is capped by the enamel.

17. The number of milk-teeth is twenty.

18. Each jaw of an adult should contain sixteen teeth: four incisors, two canines, four bicuspids and six molars.

LESSON V.

THE TRUNK.

3. EXPERIMENT.—**The carcass of a quadruped,** if placed in a wooden box punctured on all sides, and buried in the ground close by an ant-hill, will after a few weeks be reduced to a skeleton, which may be used to advantage in studying the human skeleton.

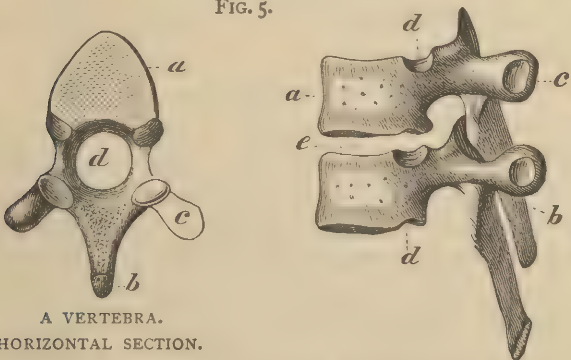
The skull is supported by an upright column, called the spinal column or *back-bone.* It consists of twenty-four separate vertebræ, which are so fastened together that the entire number appears as an unbroken pillar, forming the central, most important, and, let us add, the most wonderful part of the skeleton. Nearly all the organs of the body seem to rely upon it for their support. It helps to form the back wall of the chest and abdomen, which are maintained by the pelvis or *haunch bone.*

The vertebræ and joints of the back-bone may be ascertained by the touch; they begin with the back part of the neck and pass down to the pelvis. In a similar manner locate the ribs, which extend from the right and left of each vertebra in the thorax and encircle the chest. They are fastened in front to the breast bone or *sternum.* Find the two collar bones or *clavicles*, and observe their form. Next examine the

two shoulder-blades; together with the clavicles they form the shoulder, and protect the lungs from above.

The vertebræ are perforated, that is, they contain a nearly oval cavity about an inch wide, filled with the spinal cord (Fig. 5, *d*). This cord extends down to the lower end of the pelvis. The spinal column protects the spinal cord within; it serves to bear the head aloft and to give the body its erect position.

FIG. 5.



A VERTEBRA.
HORIZONTAL SECTION.

TWO VERTEBRÆ.—SIDE VIEW.

Each vertebra presents the appearance of a hollow cylinder, to the rear portion of which are attached seven superficial elongations or *processes* (Fig. 5, *b* and *c*). These processes are joined to ribs, ligaments (Lesson VI.) and muscles.

The number of ribs fastened to the sternum is fourteen, seven on each side. The eighth and ninth ribs, on each side, do not reach far enough to the front; the tenth, eleventh and twelfth are shorter yet. These ten ribs are called the 'false' ribs.

Between each pair of vertebræ is an interstice of about one-sixth the height of the body of the vertebra. This space (Fig. 5, *e*) is occupied by two layers of cartilage, attached to the two bones. These cartilages render the spine elastic, and make its joints yield and work with ease. (All of the bones named in this connection, except the body of each vertebra, are flattened and without cavity.)

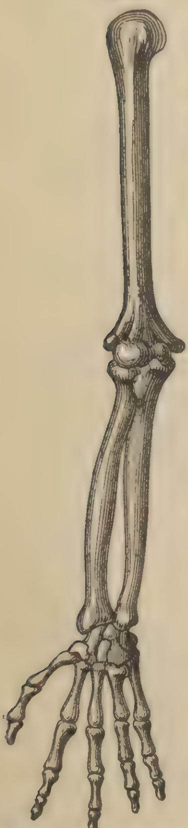
The pelvis supports the spinal column and the abdomen. It is formed by the two hip-bones, which are held together by the lower part of the spinal column, the *sacrum*.

During the day the spinal column, while in erect position, supports the weight of the head, arms, and nearly the entire trunk. This compresses the layers of cartilage between each pair of vertebræ so as to diminish the length of the column. Hence, the human body is actually a little shorter toward evening, and resumes its normal length when lying in a horizontal position, or after a night's rest. Elderly persons shrink in height, because their intervertebral cartilages harden and become thinner; this accounts for their stooping posture. Persons in the habit of bending the head forward too far compress the front part of those cartilages, while the rear portion thickens. In course of time the cartilages lose their elasticity, and the spine becomes curved or 'crooked.' The erect position of the spinal column is one of the essential requirements of health.

LESSON VI.

THE LIMBS.—LIGAMENTS.

Fig. 6



Bones of the Arm and Hand.

Examine your arms, and locate their bones. You will find a long bone in the upper arm, and two long bones in the lower. So there is in the upper leg a long bone, the longest and strongest bone in the skeleton; and there are, also, two long bones in the lower leg.

The hand (Fig. 6) is composed of three parts: the fingers, the palm and the wrist. The wrist contains eight little bones, placed in two rows; together with the bones of the fore-arm, they form the wrist-joint. The palm has five bones. The four fingers have three bones each; the thumb contains only two. The entire hand, therefore, contains twenty-seven bones.

The foot, in a similar manner, is composed of the toes, the metatarsus, and the tarsus or instep. The great toe contains two bones; the remaining toes, like the fingers of the hand, have three bones each (Figure 1). The instep has seven

bones; the metatarsus, five. In all, there are twenty-six bones in the foot. The heel supports the rear portion of the foot, or the whole body when the body is in erect position.

The *knee-pan* covers the forepart of the knee-joint.

The mechanism which adapts the limbs in the human body to their manifold uses is remarkable for its effective plan and devices. No animal exhibits a system of joints which is movable in so many directions, and yet is so firm and stout. No animal possesses such gracefulness in the motions of its limbs, combined with so vast a capacity of exertion and endurance.

The limbs are joined to the trunk in a manner such that they enjoy motion in every direction—upward, downward, forward, backward, and in a circular manner. This is secured by a *ball-and-socket* joint where the globular-shaped head of a bone plays in a cup or socket. The elbow and the ankle have each a *hinge-joint*, which allows forward and backward motion only.

The foot does not rest upon its whole lower surface, but, having the form of an arch, it touches the ground only at the heel and at the ball of the toes in front. All the bones composing this arch, or "hollow of the foot," are fastened to each other by ligaments in such a manner as to give them a large amount of spring-force with which to resist the effects of pressure produced by the weight of the body and by the jar against the ground. To convince one of the truth of this, he needs but place the hollow of the foot upon the round of a ladder.

Ligaments.—The movable joints are fastened together by ligaments. Ligaments are firm, fibrous bands with very little mobility. The bone to which a ligament is fastened may be broken by an accident, without harm to the ligament itself. If our joints were formed by the direct contact of bones, these bones could scarcely play upon each other; hence, there is cartilaginous tissue between them, to give them a greater or less amount of play and elasticity. In the movable joints the surfaces which play upon each other are covered with cartilage. Moreover, they are enveloped by a sort of sac, which secretes a lubricating fluid resembling the white of an egg.

Familiar facts.—Animals can not move their claws separately; man is able to move any of his fingers independently. No animal except the bat is competent, with his fingers, to make a span equal to the entire length of the hand. While many an animal has something like fingers; while the bird possesses a flying apparatus, and the horse greater capacity for running than man, man alone has so perfect a machine as the human hand with which to execute such complicated motions and to assume such manifold positions and forms.

Read *Dress and Care of the Feet.* Sam. R. Wells, Publisher, 389 Broadway, New York.

Read *The Hand*, by Sir Charles Bell. Harper & Bros.

LESSON VII.

CARTILAGES — LARYNX — TRACHEA.

Examine, and compare with each other, the nasal cartilage, the external ear and the gullet of a bird. The first is an appendage to a bone, the second is not directly connected with any bone, the third is a structure entirely independent of bones. All three are illustrations of a dense, firm substance, called cartilage or gristle. It is nearly related to bone, but lacks the mineral ingredients of bone, and is, therefore, softer and more elastic.

The chief uses of cartilage are the following:

(1.) To yield smooth surfaces for easy friction in the joints; and to act as a cushion in shocks.

(2.) To fasten bones together without destroying freedom of movement, as between the vertebræ.

(3.) To serve as a firm yet not unyielding framework, as in the larynx and trachea.

(4.) To adapt itself to all purposes where firmness, toughness, elasticity and strength are required.

The Larynx. — To the rear of the tongue is an aperture, the *glottis*, with a sort of fleshy cover, the *epiglottis* (Fig. 7). This aperture leads to a cavity, the larynx, whose sides are composed of cartilage.

The lower continuation of the larynx forms a long tube, the *trachea* or windpipe, composed of cartila-

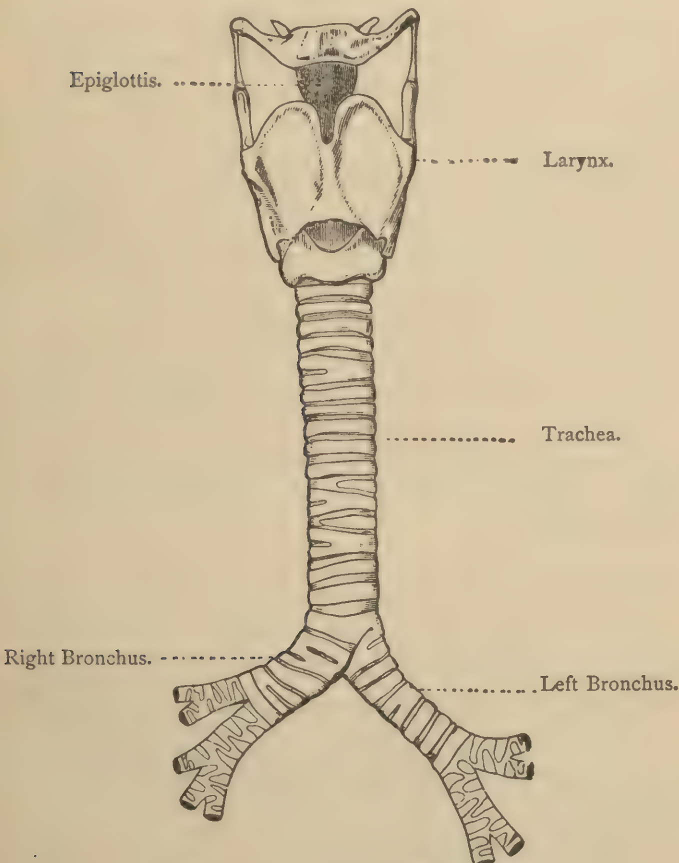


FIG. 7.—LARYNX AND TRACHEA.

ginous rings, some of which may be felt from with-

out. These rings are complete only in front; in the rear, where the trachea rests against the gullet, their ends are connected with each other by a thin membrane and by muscular fibres.

The trachea, after entering the thorax, separates into two branches, the right and left *bronchi*. These enter the lungs and divide further into a great many smaller bronchial tubes.

The larynx is the organ of the voice. It contains within its cartilages, immediately below the epiglottis, two elastic lips, known as the vocal chords. These chords are controlled by certain muscles, so that they can close the larynx against the passage of air to or from the lungs. They can also be relaxed, or shortened and lengthened, so as to throw currents of air passing between them into vibrations — that is, so as to produce sound. During inspiration the vocal chords are widely separated; during expiration they relax somewhat, and are nearer together.

QUESTIONS:

1. Why is not the spinal column made up of a single bone in place of the vertebræ?

2. Why are not all the ribs attached to the sternum?

3. When has the human body greater length than usual?

4. State why this is the case.

5. How does a bone differ from cartilage?

LESSON VIII.—REVIEW.

LESSON V.—

1. The spinal column directly supports the skull; it is itself supported by the pelvis.

2. The spinal column consists of twenty-four separate bones or vertebræ.

3. The trunk contains the spinal column; twenty-four ribs, twelve on each side; the breast bone, two clavicles and the two shoulder-blades; two hip-bones and the sacrum.

4. The spinal column protects the spinal cord within; it serves to bear the head aloft, and to give the body its erect position.

LESSON VI.—

5. The arm is composed of a long bone in the upper arm, two bones in the lower, and twenty-seven bones in the hand.

6. The leg is composed of a long bone in its upper part, two bones in the lower, and twenty-six bones in the foot.

7. The ball-and-socket joint permits motion in all directions; the hinge-joint, only in two.

8. The arch of the foot renders the foot better capable of supporting the weight of the body.

9. The movable joints are fastened together by ligaments. Ligaments are firm, fibrous bands with very little mobility. The bone to which a ligament is fastened may be broken by an accident without

harm to the ligament itself. If our joints were formed by the direct contact of bones these bones could scarcely play upon each other; hence, there is cartilaginous tissue between them, to give them a greater amount of play and elasticity. In the movable joints the surfaces which play upon each other are covered with cartilage. They are enveloped by a sort of sac, which secretes a lubricating fluid resembling the white of an egg.

LESSON VII.—

10. The chief uses of cartilage are: 1. To yield smooth surfaces for easy friction in the joints, and to act as a cushion in shocks. 2. To fasten bones together without destroying freedom of movement, as between the vertebræ. 3. To serve as a firm yet not unyielding framework, as in the larynx and trachea. 4. To adapt itself to all purposes where firmness, toughness, elasticity and strength are required.

11. The larynx consists of a cavity surrounded by cartilages; it is the organ of the voice.

12. It contains the vocal chords, which produce sound by causing currents of air passing between them to vibrate.

13. The trachea consists of cartilaginous rings, which are complete only in front.

14. The right and left bronchi are two branches of the trachea; they divide into finer bronchial tubes.

15. The epiglottis serves as a protection to the larynx.

LESSON IX.

MUSCLES—FAT.

4. EXPERIMENT.—**Stretch out one arm** and let its upper part be grasped by another person. Then slowly bend up the fore-arm; the person will now feel that a portion of the upper arm is swelling; in fact, there is now a compact mass of flesh which was not observably so prominent before, and which relaxes again when the arm is stretched out. Could we remove the skin after the arm is bent up, we would find a mass of red flesh or muscle, called the *biceps* muscle.

The motion of this muscle is, like all motion, the manifestation of a force; in the present case, the force of the will. The flesh or muscle is the carrier of this force.

A muscle is an aggregation of minute fibres, each of which is again composed of minute fibrils, held together by a delicate membrane. All the motions in the animal body are performed by muscles. Muscles, generally speaking, are the organs of motion.

The above experiment shows that muscles produce motion by means of their *contractility*. This is the first property of muscles. Contractility implies the power of shortening and lengthening, and it is

in this way that muscles move the bones to which they are attached. The second property of muscles is their *sensibility*. As a general thing, healthy muscles are not very sensitive; witness the slight pain caused by a cut in the flesh. Their sensibility consists in this, that they can communicate to the mind the state and condition in which they are. If, for example, a muscle is fatigued, or in a state of cramp, we immediately become conscious of it.

About ten minues after death the muscles of the body pass, spontaneously, into a state of contraction very nearly like that which takes place during life. This produces a general stiffness of the entire body, and is known as the *rigor mortis*, or *post-mortem rigidity*.

There are two kinds of muscles, distinguished by their structure and mode of action: *first*, the *voluntary* muscles, as the biceps and nearly all the muscles used for moving bones. The action of voluntary muscles is, to a large extent, controlled by the will. *Second*, the *involuntary* muscles, as in the trachea, the bronchi and the digestive canal. These muscles are beyond the control of the will. Thus, whether we will or not, the process of respiration goes on day and night. The roughness of skin, called *goose skin*, is caused by the action of involuntary muscular fibres in the skin. It is usually the result of cold, electricity, or sudden mental impressions.

In children, and in some adults, we notice a soft tissue, called *adipose* tissue, or *fat*. It exists in

nearly all parts of the body. Its chief uses are the following:

1st. The fat, which is situated directly beneath the skin, prevents much of the heat of the body from escaping, because fat is a bad conductor of heat or cold.

2d. Fat serves as an elastic packing material to wrap delicate structures, such as the palm of the hand and soles of the feet.

3d. It serves as a store of combustible matter—that is, it may be burnt up in the system, and thus become a source of heat to the body.

4th. It serves to fill the cavities of the long bones. It is then called marrow.

Read *Woman's Form.* Harper's Magazine, Vol. 37, July, 1868.

LESSON X.

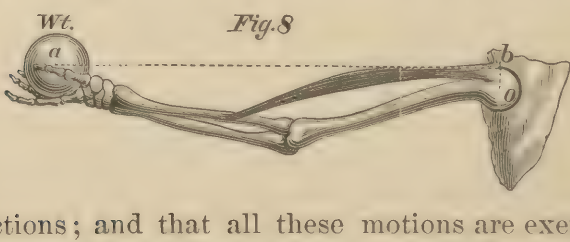
MUSCLES AS MOTOR AGENTS—WALKING.

[First read Lesson XVI, "The Lever," in Hotze's First Lessons in Physics.]

5. Experiment.—Straighten the arm and extend it horizontally; place a five-pound weight on the hand. To uphold this weight a muscular effort, or force, of about 100 pounds is required, to say nothing of the effort to sustain the weight of the arm itself.

Before investigating this phenomenon, the young student should be reminded that the human arm is a lever with its point of support, or fulcrum, at the point *o* (Fig. 8) in the shoulder-joint; and that, in virtue of this joint being a ball-and-socket joint (page 28), the arm enjoys motion in a variety of

Fig. 8



directions; and that all these motions are exerted by strongly-developed muscles, extending from the shoulder-blade, clavicle and thorax to the upper arm, to which they are attached (pp. 43 and 45.)

The weight (Fig. 8) is supported by a shoulder-muscle, through which the power is exerted at the point *b*. Joining the points *o*, *b* and *a* (the weight) by straight lines, a bent lever, *o b a*, with fulcrum at *o*, is formed. The weight evidently operates at the end of the long lever-arm, *a b*, while the muscular power at *b* operates only by the short lever-arm, *o b*. The ratio of the two lever-arms is about as 20 to 1. This explains why the five pound weight, at the end of the long arm, acts with a momentum of nearly $5 \times 20 = 100$ pounds; and why the strong shoulder-muscle at the end of *o b*, in order to balance this momentum, must pull upward with a force of (nearly) $100 \times 1 = 100$ pounds. It also accounts for the fact, known to every one, that it requires exertion to hold the arm extended, even without any additional weight in the hand.

The strong shoulder-muscle here mentioned is omitted in Fig. 8, because it would prevent *o b* from being seen. This muscle is the chief but not exclusive supporter of the weight of the ball and that of the extended horizontal arm; in this it is assisted by other muscles, among which is the biceps—the muscle visible in Fig. 8.

The lever, *o b a*, is a lever of the third class, the power being applied between the fulcrum and the weight. A pair of tongs with which to lift lumps of coal is also a lever of the third class. If, now, with a little imagination, we compare the point where the tongs are riveted together with the point below each ear where the jaws come together; and if, fur-

thermore, we imagine each half row of teeth to be a lever similar to one of the levers of the tongs, then half the upper jaw, with its lower half attached, forms a pair of levers like a pair of tongs. The farther to the rear the resistance to be overcome by the teeth be placed—that is, the nearer to the fulcrum—the shorter do we make the lever-arm at the end of which the weight or resistance operates, and the less muscular effort is required. It follows, then, that the jaws exert the greatest force between the hindmost molars. Toward the front part of the jaw the teeth lose their grinding power, and it is a wise provision of nature that the front teeth, having but small capacity otherwise, possess a knife-shaped form.

From the preceding it would appear that a large amount of muscular force exerted by a human being during the day is wasted; but we must remind ourselves that much of the force apparently lost is realized as a gain of time, a convenience of direction, and as a greater range of motion.

It should be stated here that nearly all muscles terminate at their ends, where they are attached to bones, in sinewy, inelastic cords, called *tendons*. Tendons form the connecting link between muscle and bone, just as ligaments between bone and bone. The leg of a turkey furnishes an abundance of tendons.

Standing.—When the centre of gravity of a body is supported, the entire body is supported. The centre of gravity in the human body lies in the ab-

domen. In order that a person may stand erect, therefore, the centre of gravity must be supported by the legs. This requires work on the part of all the muscles below the trunk. The amount of this work is very great; this is proved—(1) by the difficulty which a little child experiences in learning to stand erect; (2) by the necessity which the adult experiences while standing, of frequently shifting the centre of gravity, throwing it alternately over one limb, so as to allow the other to rest for a short time.

Walking.—This act comprises,

(1) *The lifting of the body.* This is accomplished by lifting the leg; that is, by increasing the distance between the toes and the centre of gravity. During this action, the same leg supports the entire weight of the body; the other leg, having at the time no load to carry, swings freely forward, after the manner of a pendulum.

(2) *The forward motion of the body*, and its subsequent downward motion as the foot of the other leg is planted on the ground.

(3) *The forward swinging of the leg.* The other leg now bears the weight of the body, while the first leg swings freely forward. This mechanical forward swinging requires scarely any muscular exertion; hence it affords alternate rest to each limb.

Although the entire weight of the body is carried alternately by one foot, yet an hour's walk is less fatiguing than to stand still for an hour, because, in walking, each limb enjoys alternate rest.

LESSON XI.

MUSCLES, CONTINUED—WORK OF MUSCLES—LEAPING.

Muscles remain contracted only for a short period. They soon relax, and during relaxation their previous strength is regained. In walking, the muscles are constantly changing from contraction to relaxation, while the erect position of the body requires the activity of all the muscles; for those muscles which are situated in front prevent the body from inclining backward, while those behind prevent the body from bending forward. The muscles upon the sides of the body act in a similar manner. This explains why to stand erect and motionless for a given time is much more tiresome than to move about during an equal length of time. We gather new strength when we rest or sleep; complete rest is found only in a lying position.

The muscles are wrapped in a tissue which is found in nearly all parts of the body; it envelopes the muscles, it coats the bones and cartilages, and thus connects the different portions of the human body with one another. According to its different uses, it varies greatly in character, being at times soft and tender, at other times very dense and strong, as, e. g. in the tendons. It is called *connective* tissue.

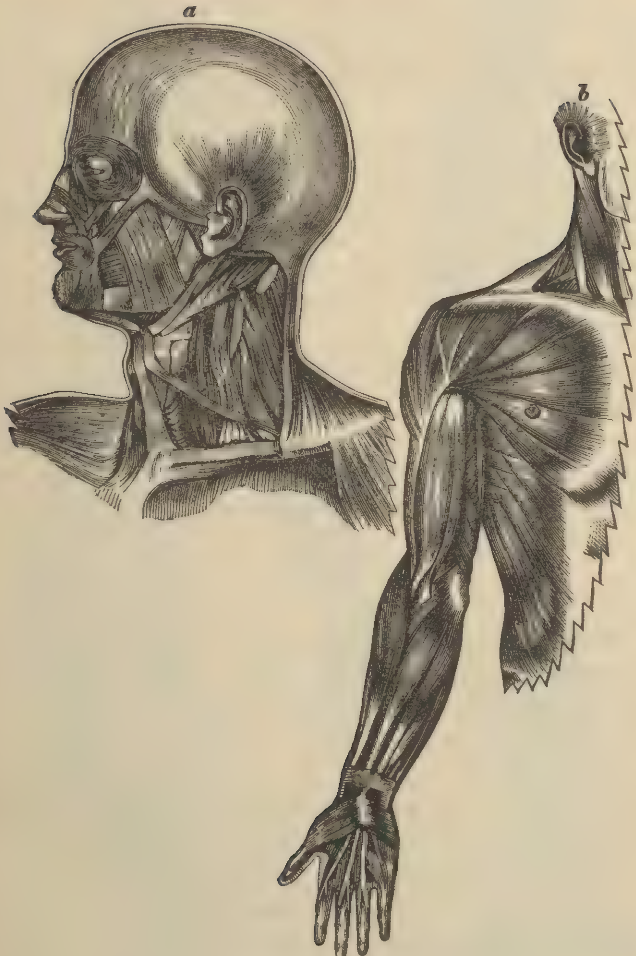


FIG. 9.—MUSCLES.

The muscles of the head and trunk perform no such intense labor as those of the limbs; hence, they are less substantial. The roof of the skull has no muscles proper, but a tendinous cap, or *helmet*, underlying the hairy skin; it may be moved by muscles in the front and rear portion of the head. The muscles of the eye are of a very delicate structure, and so arranged as to roll the eye-ball, move it slightly forward and backward, and to raise and lower the eye-lids. The tongue, the interior of the mouth, the throat, in fine, all the parts of the body, have suitable layers or strings of muscles in order to produce motion, to hold the limbs in position, and, in general, to protect the skeleton. The entire number of external muscles may be set down at two hundred and forty pairs (Figs. 9 and 10).

When a force performs work, the work is always a motion of some kind or other. The force of the will or mind, when imparted to a muscle, causes the muscle to perform work which, for the greater part, consists of motion. Motions produced by the human body are utilized mainly because of their being converted into force when they are suddenly arrested. The blacksmith, having imparted motion to his hammer by lifting it, changes this motion into force when the hammer strikes the iron upon the anvil. If the weight of the hammer $=3$ pounds, and the height of its descent $=4$ feet, the work performed by the person is $3\times4=12$ footpounds. (A footpound

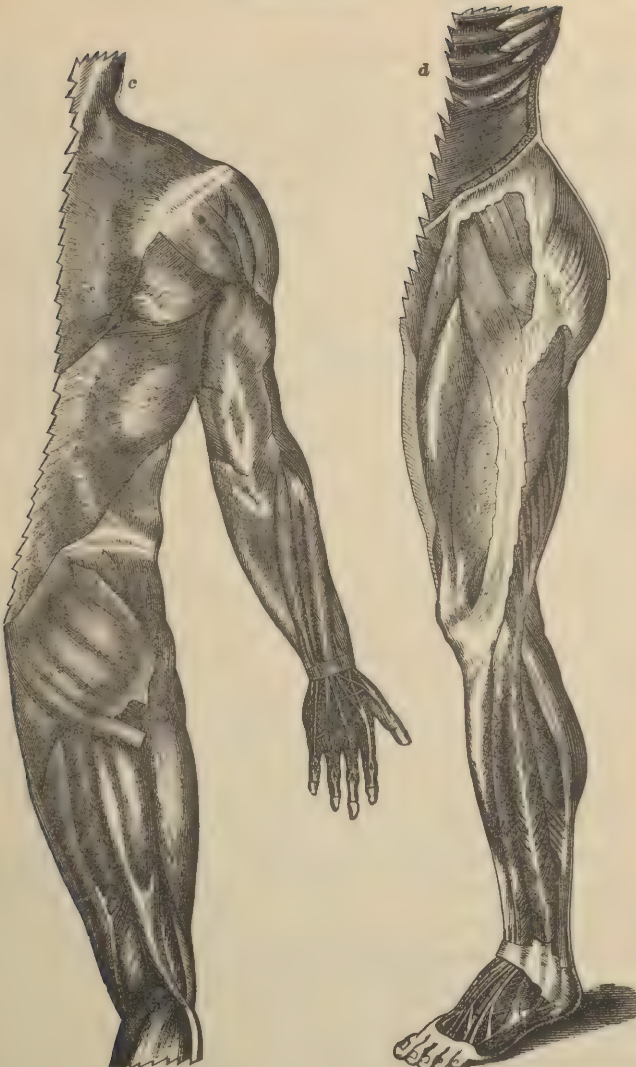


FIG. 10.—MUSCLES.

is a pound lifted through one foot of space against gravity.) But this does not tell us anything about the quantity of muscular exertion. Perhaps the following instance will make it clearer: If an adult weighing 150 pounds wishes to leap two feet high, the amount of work $=2\times150=300$ footpounds. On an inclined plane, or a stairway of gentle slope, this amount of work is performed easily in one or more seconds. But to do it by jumping seems to require a greater effort, although the amount of work performed remains the same.

Leaping is a combination of two essentially different motions: *First, the body is lifted by the action of the muscles;* of course, there must be a support under foot. *Next, the feet separate from the ground and the body rises;* gravity stops its upward motion and pulls it down again. Let us recall the above example. The first motion, viz., the lifting of the body, is effected by muscular action. It has a limited range, perhaps no more than one-half foot. Now the entire work, as we have seen, amounts to 300 footpounds, and is carried on by a muscular action through one-half foot of space. Therefore, the muscular action, that is, the entire pressure of the feet against the ground, while the body is moving upwards one-half foot, in order to produce 300 footpounds of work, must be equal to 600 pounds, for $600\times\frac{1}{2}=300$. In order that a person may be able to produce so great a pressure through the one-half foot of space, he must first assume a stooping position. It is the muscular ef-

fort required to produce this great pressure that makes the task so arduous.

The Heart (page 58) is a muscle which, by it motion, propels the blood through the body. At every contraction of the ventricles a charge of about six ounces of blood is driven into the arteries. The great velocity imparted to the blood, and the fact that during life the motions of the heart are carried on in never-ceasing successions—the heart, like the lungs, never rests while the vital processes are in function—render it, beyond doubt, that the heart incessantly performs an enormous amount of work.

The experience of a long period of years has shown, beyond doubt, that the mechanical power of the human body is used to best advantage by both employer and employee when the work is done regularly and continuously, not in separate, fitful exertions. Man's forces must not be exhausted further than rest and food can replace them day by day. In utilizing our physical forces, therefore, certain limits must be observed, a limit of exertion as well as a limit of time. Any deviation has always been followed by a deterioration in the value of the work done.

Read *The Wonders of the Human Body*. Illustrated Library of Wonders. Scribner & Armstrong, New York.

LESSON XII.—REVIEW.

LESSON IX.

1. A muscle is an aggregation of minute fibres, each of which is again composed of minute fibrils, held together by a delicate membrane. All the motions in the animal body are performed by muscles. Generally speaking, muscles are the organs of motion.

2. Muscular motion is exerted by means of the contractility of muscles.

3. Contractility and sensibility are characteristic properties of muscles.

4. Contractility implies the power of contracting and relaxing; sensibility, their power of communicating impressions directly to the mind.

5. Post-mortem rigidity is the general stiffness of the body after death.

6. Muscles are of two kinds: involuntary and voluntary; these are distinguished by their structure and mode of action.

7. Nearly all the muscles used for moving bones are voluntary muscles.

8. The trachea, bronchi and the digestive canal have involuntary muscles.

9. The chief uses of fat are:

(1.) The fat, which is situated directly beneath the skin, prevents much of the heat of the body from escaping, because all fat is a bad conductor of heat or cold.

(2.) Fat serves as an elastic packing material to wrap delicate structures, such as the palm of the hand and soles of the feet.

(3.) It serves as a store of combustible matter—that is, it may be burnt up in the system, and thus become a source of heat to the body.

(4.) It serves to fill the cavities of the long bones; it is then called marrow.

LESSON X.

10. To sustain a five-pound weight in the hand, the arm being stretched out horizontally, a muscular effort of about one hundred pounds is required. This does not include the weight of the arm.

11. The human arm is a lever of the third class, the fulcrum lies in the shoulder-joint, and the power between the fulcrum and the weight.

12. Muscles usually terminate in tendons.

13. Tendons connect bones with muscles; ligaments connect bones with bones.

14. Walking consists—
 (1) In the lifting of the body;
 (2) In the forward motion of the body;
 (3) In the forward swinging of the leg.

LESSON XI.

15. The erect position of the body is the result of the combined action of the muscles.

16. Connective tissue is that tissue which invests nearly all the parts of the body.

17. The properties of connective tissue vary according to its uses.

18. The muscles of the eye roll the eye-ball, move it slightly forward and backward, and raise and lower the eye-lids.

19. The uses of the muscles are—
 (1) To produce motion;
 (2) To hold the limbs in position;
 (3) To protect the skeleton.

20. Human labor should be performed with continuance and regularity. The forces of man must not be exhausted further than rest and food can replace them day by day.

LESSON XIII.

THE SKIN—HAIR AND NAILS—EXCRETION OF THE SKIN.

6. EXPERIMENT.—A piece of fresh animal skin, put in water, will swell up without dissolving. If now the skin be boiled in the water for several hours, most of it will dissolve, and on allowing the liquid to cool, a gelatinous substance is obtained. When dried, this forms the well-known *glue*. Nearly all connective tissue yields the same result if treated in a like manner.

The skin is the external covering of the body. It consists of two layers—the outside skin or the *epidermis*, and the inner one or *dermis*. The epidermis contains coloring matter, which gives rise to shades of tint in the skin of both individuals and races. It is of different thickness on different portions of the body; the more it is subjected to friction and pressure, the more does it grow—that is, the more does it become thick and horny.

The epidermis serves to protect the sensitive lower skin or dermis, and to moderate the evaporation of fluid from the blood vessels.

The dermis serves to invest the secretion glands; on its surface are the sensitive *touch-corpuscles*.

The dermis is the deeper portion of the skin; it is denser, more elastic and more tender than the epidermis. When cut it bleeds very freely; the epidermis does not bleed at all. In sharpening a pencil the outer skin is frequently cut, and no notice taken of it unless the knife enters a shade deeper, causing pain and flow of blood.

The general properties of the skin are toughness, flexibility and elasticity. Owing to the first, it serves as the protecting cover of the body; in virtue of the second, it shields the inner parts from violence; and, on account of the last, it yields readily to the movements of the body. But it serves yet another purpose not less important; it is the principal organ of touch (Lesson XXXI).

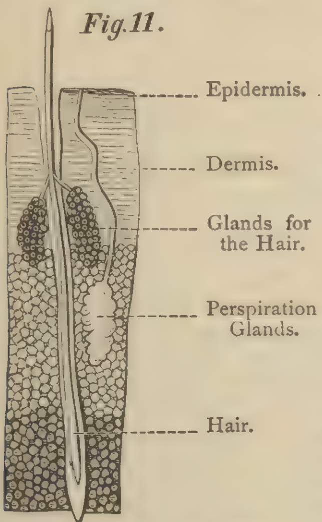
The *hair* and *nails* are peculiar forms of the epidermis. The former is composed of horny scales and cells, closely packed together. The root of a hair, together with the root-sheath in which it is imbedded, may be seen when a hair is pulled out.

Nails grow, like hair, by the constant addition of cells from beneath and behind, which take the place of portions worn away or cut off.

The secretion of the skin consists of two different fluids; one oily, the other watery. The oily one is secreted mostly in the scalp and the face, where the skin is largely supplied with hair. The other is called *perspiration* or *sweat*, the two terms being habitually taken synonymously, although there is this difference between them: perspiration

is an insensible excretion, which evaporates on the skin; sweat is a sensible secretion, composed of the same fluid as the other, but appearing on the skin in the form of drops. The passage of these fluids is effected by a multitude of fine canals or pores (Fig. 11) in the skin. Perfect health requires cleanliness, so that the activity of the pores shall not be impeded.

Fig. 11.



Sectional View of the Human Skin, Highly Magnified.

The quantity of water lost by transpiration depends, like all evaporation in the open air, upon the temperature, the saturation and the stillness of the atmosphere. In hot weather the quantity of excretion from the skin is greater than in cold. When the atmosphere is fully saturated with watery vapor, perspiration does not evaporate; and the consequence is an almost insufferable sensation of heat. The same holds true when, owing to the absence of currents of air, the watery vapors of perspiration remain around the person instead of being constantly displaced by fresh, that is, less saturated air.

Read *How to Bathe.* E. P. Miller. Miller, Haynes & Co., N. Y.

LESSON XIV.

THE BLOOD.

7. Experiment.—Allow the blood of an animal to remain quietly in a vessel. In a few minutes it will coagulate, separating into two substances—a solid and a liquid.

The solid has a dark-red color, and is a sort of jelly, often called *the clot*. The red color is due to the presence of minute bodies, which are held in suspension in the blood. Besides these red *corpuscles*, the clot contains a white, fibrinous mass, or *animal fibrine*. The liquid is called *serum*, which has a yellowish color; but if, by boiling it, we remove its water, it will coagulate to a white jelly, composed of *albumen*.

The *composition* of blood that has remained standing for some time is, therefore, as follows:

$$\text{Blood.}\begin{cases}\text{Clot.}\begin{cases}\text{Blood Corpuscles (red and white).}\\ \text{Animal Fibrine.}\end{cases}\\ \text{Serum.}\begin{cases}\text{Water.}\\ \text{Albumen.}\end{cases}\end{cases}$$

It is characteristic of the red blood corpuscles that they always contain iron.

The *specific gravity* of blood (at a temperature of 60° F.) is about the same as that of water. The temperature of the blood in the human body is generally 100° F. In the animal it has an odor faintly resembling that of the animal from which it came.

The *quantity* of blood in the living body is difficult to ascertain; it has been estimated at about one-tenth of the weight of the entire body. In a thousand parts of weight of blood seven hundred and eighty-four parts are water, one hundred and thirty parts are red corpuscles, and the remainder is composed of albumen, fibrine, fat, and other matters. The proper composition of the blood is one of the three most important items in the health of man. The ravages of cholera and of similar diseases seem to result from a decomposition of this life-giving liquid. It will be seen, further on, that the health of the blood depends largely upon our food and upon the air we breathe.

The *red corpuscles* of the human blood are cells of different sizes, having the form of discs, each of which has an area of nearly $\frac{1}{1000}$ of a square inch, and a thickness of about $\frac{1}{1000}$ of an inch. They possess the remarkable property of adhering together in columns, like rolls of pennies; these rolls, moreover, join at their ends so as to cluster together, forming a sort of network (Fig. 12).

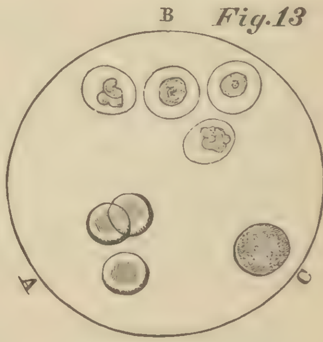
Besides the red, there are *white corpuscles* in the blood. They differ from the former in their num-

ber being much smaller than that of the red; for every five hundred red ones there exists, perhaps, one white corpuscle. During disease this ratio may increase to ten, and even more, for every five hundred. They are larger than the red corpuscles, and possess the peculiarity of alternately contracting and dilating, and otherwise changing their forms.

In Fig. 13, B, there are four white, in A C, four red corpuscles, as seen through a microscope of very high magnifying power.

Fig.12.

Fig.13



The use of these little bodies is not well determined. The main purpose of the red seems to be to convey oxygen from the lungs to all parts of the body.

The gases contained in the blood are carbonic acid, oxygen and a small quantity of nitrogen. One hundred volumes of blood contain about fifty volumes of these gases, collectively.

Of the *uses of the blood* when in the healthy state, the following four may here find a place:

(1) It is a source of nutritive material, whence the different parts of the body constantly draw for their maintenance.

(2.) It keeps all parts of the body warm and moist.

(3.) It conveys oxygen to those of the tissues which need this element.

(4.) It collects refuse from all parts of the body, and conveys the substances to places whence they may be discharged.

In the next Lesson we shall learn something about the manner in which the blood circulates through the body.

LESSON XV.

THE CIRCULATION OF THE BLOOD.—I.

8. EXPERIMENT.—**Cut open a fresh plant,** and observe its juice. Next open an *insect* for the same purpose; it contains a watery, almost colorless juice or blood. Then cut open a fish; its blood is cold. Lastly, procure some red, warm blood of a recently killed bird, or quadruped.

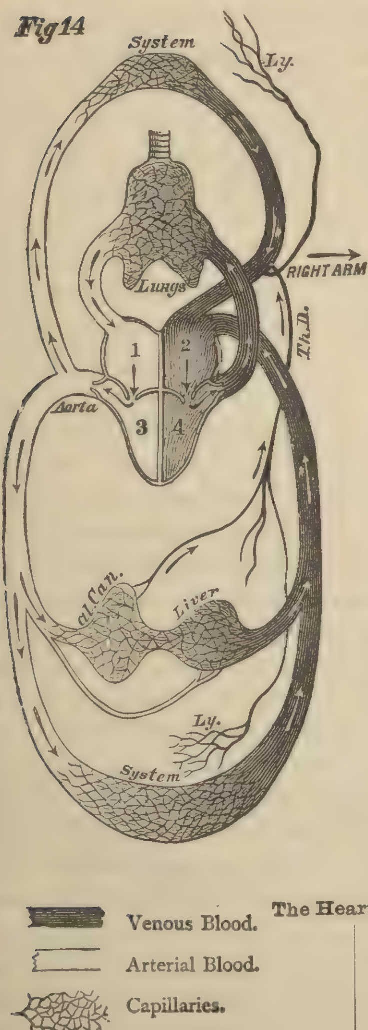
The preceding shows that organisms have a fluid circulating through the body.

Man and the higher order of animals alone possess warm blood. The 'vital fluid' has a definite order in which it travels through the animal system. The circulation in the human body is the same as in mammals and birds.

An uninterrupted current of blood through the body must be maintained. This is evident from the uses of the blood enumerated in the preceding Lesson. The question now arises, How does nature obtain such an unceasing stream rushing through countless tubes and channels?

The heart (represented by 1, 2, 3, 4, in Fig. 14) is a hollow muscle of about the size of its owner's fist. This muscle has involuntary action, consisting of alternate contraction and dilatation, which goes on without interruption until death. Owing to the con-

Fig 14



The Heart and the Lungs.

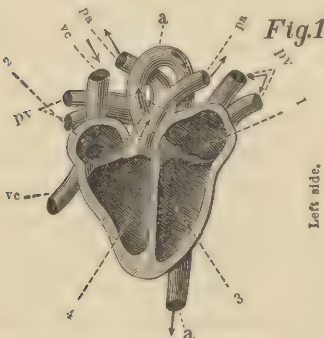
Viewed from behind, so that the position of the observer corresponds with that of the figure.

traction, the blood is expelled from the heart through *arteries* and owing to the dilatation, it returns to the heart through veins.

The heart is divided by a partition into two sides, right and left (Figs. 14, 15). These two sides do not communicate with each other. Each of them has been subdivided into two portions, an upper and a lower, or into the *auricle* (1 or 2) and *ventricle* (3 or 4) respectively. The heart, therefore, contains two auricles (1, 2) and two ventricles (3, 4). While the two divisions right and left are entirely separate

from one another, each auricle communicates with the ventricle of the same side. The opening, however, through which the communication takes place is so constructed that it acts like a valve (compare First Lessons in Physics, p. 72); it allows the blood to pass from the auricle to the ventricle, but not in the opposite direction.

Fig.15.



The Heart and Large Blood Vessels.

The course of the blood from auricle to ventricle is in the same direction on each side. The blood in the right auricle (2) is urged into the right ventricle (4), whence it passes through a large artery (pa) into the capillaries of the lungs, where it absorbs oxygen, and gives out carbonic acid. This artery is the pulmonary artery, one of the few arteries carrying venous blood, and called an artery simply on account of it being constructed like the arteries. The blood is then gathered up again and conveyed in large veins (pv) to the left auricle. From the left auricle it emerges into the left ventricle (3), the strongest of the four divisions, and thence into the *aorta*, *a*, the strongest of the arteries. The aorta distributes it all over the system, to the capillaries of every portion of the body. In these capillaries the blood becomes impure, and after leaving them it passes through the large veins (vc) back into the right auricle (2), whence we supposed it to start.

As stated before, the chief propelling force for the incessant torrent of blood through the body lies in the muscular substance of the heart. But there are several helpers which must not be disregarded: 1st, the elastic walls of the arteries (they are not unyielding like gas pipes); 2d, the pressure of muscles upon some of the veins; and 3d, the contraction and expansion of the chest in breathing. These aids will be better understood hereafter.

The function of each subdivision of the heart may be stated thus:

a. The right auricle receives the venous blood of the whole body and conveys it to the right ventricle.

b. The right ventricle impels the venous blood through an artery into the lungs.

c. The left auricle receives arterial blood flowing to it through veins from the lungs.

d. The left ventricle forces the blood into the aorta, which distributes it over all parts of the body.

In comparing the functions of these subdivisions with one another it is found that—

I. The auricles *receive* blood;

The left auricle receives arterial blood from the lungs;

The right auricle, venous blood from the entire body.

II. The ventricles *convey away* blood;

The left ventricle conveys away arterial blood to the entire body;

The right ventricle, venous blood to the lungs.

LESSON XVI.

THE CIRCULATION OF THE BLOOD.—II.

Examine the movements of the heart by placing the fingers between the fifth and sixth ribs, slightly to the left of the breast-bone (as the lower part of the heart inclines a little toward the left). Each contraction of the heart will then be distinctly felt, because the point of the heart strikes against the wall of the chest.

The heart of a living animal, if quickly removed, will continue pulsating for some time. Each pulsation commences at the two auricles, and thence passes to the two ventricles. That is to say, each pulsation of the heart consists of—1st, a simultaneous contraction of both auricles; 2d, immediately after this a simultaneous contraction of both ventricles; and third, a moment of rest or relaxation.

After this rest the contractions commence again in the same order as before, and the relaxations occur also in the same order as before. The work of the heart is carried on, as all labor should be, regularly and continuously, with due regard to rest.

The two contractions of the heart with its subsequent repose, are often represented by two short marks and a rest, thus: ⌣ ⌣ —. The contraction of either auricle or ventricle is called its *systole;*

the pause during the dilatation of either auricle or ventricle is called the *diastole*. This disastole or pause occupies about the same length of time as the two systoles together; so the heart's action has a certain rhythm.

The action of the heart may now be explained. It is filled with blood, and the first contraction, or the systole of the auricles, happens. The auricles are, as it were, pressed together, and the liquid within is forced out. Where can it go? On examining Fig. 14 two outlets are found to exist. It may pass back into the veins, or else descend into the ventricles. The amount of resistance encountered in each direction will decide the question. The resistance encountered toward the veins is very great, because exerted by the blood in all the veins; that encountered toward the ventricles will be exceedingly small, because, in the first place, the valves leading into the ventricles are open; in the second place, the walls of the ventricles, in their relaxed state, are easily expanded; and in the third place, the resisting pressure of the arterial blood is rendered naught by the valves between the ventricles and arteries being closed. For these reasons only very little blood will pass back to the veins; nearly all of it rushes at once into the ventricles. When the ventricles are thus filling they become expanded, and the blood getting behind the valves which separate each auricle from its ventricle, the ventricles are soon closed. The contraction of the auricles now ceases, their walls relax, and immediately blood from the veins enters them, slowly ex-

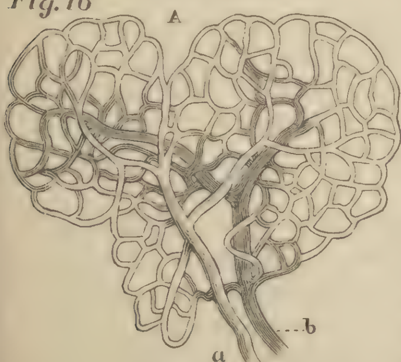
panding them again. The auricular systole is now over.

The next movement of the heart is the contraction of both ventricles. The walls of the ventricles are strong and thick; the pressure, therefore, which they produce in suddenly contracting is very great, and has the effect of shutting up the auriculo-ventricular valves so that not a drop of blood can enter the auricles. But it is toward the arteries that the ventricles meet with most of the resistance. There is the resisting pressure of the blood in the arteries, a pressure which is very great because it is made up—*first*, of the weight of the blood; *second*, of the resistance of the walls of the arteries to further expansion; *third*, of the friction of the blood in the capillaries. All this explains why the walls of the ventricles are built so very strong: they have more work to perform than the auricles. It also shows the necessity of the valves between the auricles and ventricles, and that no valves are needed between the auricles and veins. The auriculo-ventricular valves act like the lower valve in a pump. The whole office of the auricles seems to be to fill the ventricles. And the contraction of the left ventricle forces the blood into the arterial system of the body, while the contraction of the right ventricle impels the blood into the artery of the lungs. This simultaneous contraction of the ventricles forms the ventricular systole.

The arteries receive a fresh supply of blood at every systole of the ventricles; during a part of the

time in which they transmit the shock, the diastole of the heart occurs. Each ventricle contains about three ounces of blood; the whole of this passes, at each contraction, into the respective arteries. The great pressure of this quantity of blood (about one-fifth of the pressure of the atmosphere) suddenly forced into the main arteries, necessarily distends them, because they are elastic and yielding; but a reaction takes place, and the elastic walls of the arteries contract again. This contraction has two effects in opposite directions: it causes, *first*, the valves between the arteries and ventricles to close instantly; *second*, the blood to pass from the larger to the smaller arteries. Thence the fluid enters the ramification of the capillaries (Fig. 16). A little reflection will show that a corresponding quantity of blood passes at the same time from the capillaries through the veins back toward the heart. *The effect*, then, of the ventricular systole is—1st, the propulsion of blood through the arteries into the capillaries; and 2d, the return of the fluid from the capillaries through the veins to the heart.

Fig. 16



CAPILLARIES.

The impulse given at every ventricular systole to

the blood in the aorta is spent in urging the blood forward through the arteries; and, next, in distending the elastic walls of the arteries. This sudden expansion produces a sudden recoil, and gives rise to a phenomenon, which is called the *pulse.* The pulse proper is the expansion of the artery, felt on examining the artery. Each pulsation naturally means a systole of the ventricles. Such pulsations may be felt wherever arteries are exposed to the touch, as on each upper side of the neck, in front of the ear, or above the wrist. At the wrist the pulse is felt to be a little later than at the heart or middle of the neck. It occurs later, according to the distance from the heart at which the artery is examined. To feel the pulse, the wrist is selected by physicians for convenience sake. The pulse is the index of the motions of the heart. Its regularity, strength, fullness, and a number of peculiarities, indicate the state of affairs respecting the heart and its fluid.

The sounds of the heart may be distinctly heard by placing the ear closely over the heart. They should occur with great regularity—first, a prolonged, dull sound, somewhat like that of the word *lubb;* then a short and sharp sound, nearly like that of *dub;* then comes a pause; then the long sound again, and then the short sound; then the pause, the long sound, and so on. The sharp, short sound comes from the sudden closing of the valves between the ventricles and the arteries; the cause of the long sound is not fully known, as yet.

The capillaries are pulseless, because on reaching

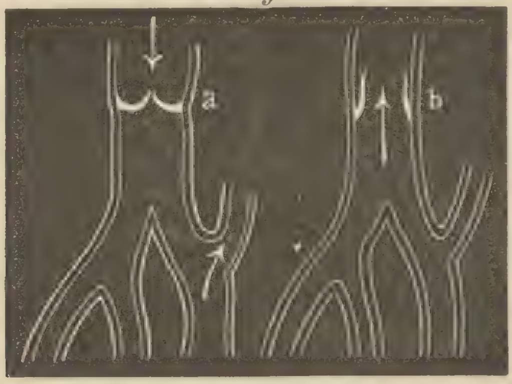
them the shock is spread over a large network of capillary tubes; this makes its effect imperceptible. For the same reason, the blood in the capillaries flows steadily, while from a severed artery it jets forth in jerks. The elasticity of the arteries seems to do for the blood what an air chamber does for the water of a pump.

From what has been said in regard to the arteries, their uses chiefly are—*first*, to convey blood to the system, and *secondly*, to convert the jerking motion of the blood into a uniform flow.

9. EXPERIMENT.—Clasp the lower part of the arm tightly a little above the wrist; the veins on the back of the hand will soon distend, and knotty points become visible. When the pressure is removed they will empty themselves, and the swelling disappears. Now, why did this not completely check the circulation of the blood? There are two reasons: In the first place, the veins communicate with each other by means of many branches, so that whenever the blood, for any reason, be stopped in one vein, it at once passes through branch vessels to another, unimpeded vein, and finally to the heart. But it may be argued that in the above experiment the arm had been encircled with so much pressure that even the branch vessels were closed. Circulation would, nevertheless, have continued, because, in the second place, the veins are provided with valves (Fig. 17) which are open as long as the fluid flows toward the heart, but which close when it moves in the opposite direction. Those knotty places were

the closed valves, preventing the backward flow of the blood to the capillaries. Were it not for this valvular action in the veins, any such disturbance as the one occasioned by the experiment, would

Fig. 17.



impel the blood to the capillaries, where it would resist, and finally overcome, the onward motion of the blood in the arteries, which would speedily interrupt the circulation.

The frequency of pulsations depends upon the age, sex and health of a person. During the first years of life about 130 pulse-beats may be counted in a minute, while twenty years later the same person's pulse will beat nearly 70 times, and increase again toward old age. The pulse of women beats more rapidly than that of men.

Read *First Series of Science Lectures.* John Heywood: Deansgate, Manchester.

LESSON XVII.—REVIEW.

LESSON XIII.—

1. Connective tissue, when boiled, yields gelatine.

2. The skin consists of the dermis and epidermis.

3. The use of the dermis is, to invest the excretion glands, and to bear the touch-corpuscles.

4. The use of the epidermis consists in protecting the dermis, and limiting the evaporation from the blood vessels beneath.

5. The general properties of the skin are—1st, toughness, which enables it to serve as a cover to the body; 2d, flexibility, by which it protects the muscles; and 3d, elasticity, by which it yields readily to the movements of the body.

6. The skin is the principal organ of touch.

7. The hair and nails are peculiar forms of the epidermis.

8. The excretion of the skin consists of oily matter, and of perspiration or sweat.

9. The amount of transpiration depends upon the temperature, saturation and stillness of the atmosphere.

10. The skin excretes about one-fiftieth as much carbonic acid gas as the lungs.

LESSON XIV.—

11. Animal blood, after standing for some time, contains—1st, red and white corpuscles; 2d, animal fibrine; 3d, water; and 4th, albumen. The first two form the clot, the remaining two the serum.

12. The specific gravity of blood = 1, very nearly; its temperature = 100° F., nearly.

13. The living body contains a quantity of blood of about one-tenth of its own weight.

14. A thousand parts of weight of blood contain 780 parts of water, and 130 parts of red corpuscles; the remainder is composed of albumen, fibrine, fat, and other matters.

15. The proper composition of the blood is one of the three most important requirements for health. (For the other two see pp. 81 and 88.)

16. The red blood corpuscles differ from the white in this: that they are smaller in size but larger in number, and of a less changeable nature.

17. The use of the red corpuscles seems to be to convey oxygen from the lungs to all parts of the body. The use of the white is not fully known. (Compare Lesson XXVII.)

18. The blood contains, dissolved within it, three gases: carbonic acid, oxygen, and a small quantity of nitrogen. 100 volumes contain about 50 volumes of these gases, collectively.

19. The following are four uses of the blood:

(1) It feeds the different parts of the body, which depend upon it for their maintenance.

(2) It provides the entire body with warmth and moisture.

(3) It carries oxygen to the tissues which need this gas.

(4) It gathers refuse matter throughout the body, and conveys it where it may be discharged.

LESSON XV.

20. Organisms of every kind need a fluid which circulates through the body and nourishes all the parts of the body.

21. The human heart is a small hollow muscle, with involuntary action consisting of alternate contraction and dilatation.

22. Arteries are vessels conveying the blood from the heart; veins are vessels conveying the blood to the heart.

23. The force which propels the blood through the body lies in the substance of the heart. Its assistants in this are: 1st, the elastic walls of the arteries; 2d, the muscular pressure upon some of the veins; 3d, the contraction and expansion of the chest in breathing.

24. The right side of the heart is entirely separated from the left side. Each is subdivided into an auricle and ventricle. The heart contains two auricles and two ventricles.

25. Each auricle communicates with its ventricle, below, by means of an aperture provided with a valve.

26. The circulation of the blood takes place in the following manner: The blood leaves the right auricle of the heart and enters the right ventricle; thence it flows through an artery to the lungs; from the lungs it passes through several veins to the left auricle, whence it is impelled into the left ventricle. It then rushes into the aorta, and is forced through every portion of the body. It finally returns through veins to the right auricle, whence we supposed it to start.

Lesson XVI.

27. A pulsation of the heart consists—

(1) Of a contraction of the auricles;

(2) Of a contraction of the ventricles;

(3) Of a pause.

28. The contraction of either auricle or ventricle is called its systole; the pause during the dilatation of either is called the diastole of the heart.

29. During the auricular systole the blood rushes from the auricles into the ventricles.

30. During the ventricular systole the blood is forced into the arterial systems of the body and lungs.

31. The contraction of the arteries has two effects in opposite directions: 1st, the closure of the auriculo-ventricular valves; 2d, the propulsion of blood from the larger to the smaller arteries.

32. The general effect of the ventricular systole is the propulsion of blood through the arteries into the capillaries, and back through the veins to the heart.

33. The pulse is the expansion of the artery, caused by the passage of a wave of blood at every ventricular systole.

34. The sounds of the heart are two: a long sound and a short one; they are succeeded by a rest.

35. The capillaries are pulseless.

36. The chief uses of arteries are: 1st, to convey the blood to the system; 2d, to produce a uniform motion of the blood.

37. Whenever the flow in the veins of a limb is checked, the branch-vessels and the valves of the veins prevent the interruption of the circulation.

LESSON XVIII.

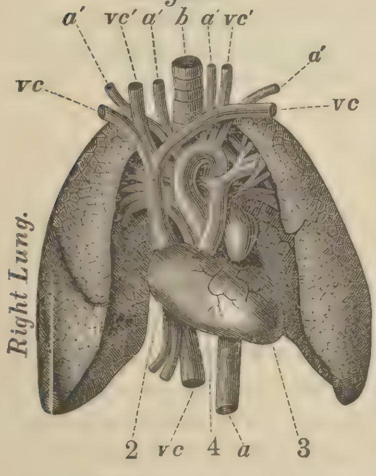
THE LUNGS.

The blood nourishes the different parts of the body (Lesson XIV.), and at the same time removes effete matter—that is, all such particles as have served their function in the body. This gives rise to two distinct kinds of blood, the *arterial* or nutrient, and the *venous*, the carrier of waste matter. The most important difference between the two is, that venous blood contains less oxygen and more carbonic acid gas than the arterial. The latter is of a scarlet color, but in passing through the capillaries of the body it is converted into venous blood, at the same time becoming darker. The venous blood passes from the heart to the lungs, where it is converted into arterial blood by the absorption of oxygen gas. This conversion is mainly effected by the peculiar structure of the lungs; it is aided by the acts of inspiration and expiration, as well as by other processes. The conversion takes place during the passage of venous blood through the capillaries of the lungs (Fig. 21).

The lungs occupy the greater portion of the chest; they are situated on both sides of the heart (Fig. 18). They receive air through the trachea and the larynx; these communicate with the external air by two channels—the mouth and the nasal tubes. The

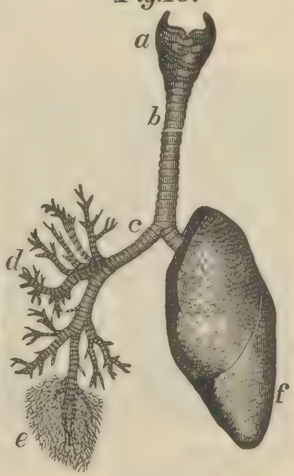
mouth can be opened or closed at will; the nasal passages are not subject to the will. The left lung consists of two separate portions called *lobes;* the right lung has three lobes (See Fig. 18). Each lung is composed of a spongy, elastic substance, and is often compared to a bag. Each is attached to one of the two bronchi (Fig. 19, *c*). These bronchi, or bronchial tubes, after entering the lungs,

Fig. 18.



Lungs, Trachea and Heart.
a Aorta. *á* Arteries.
b Trachea. *vc* Veins entering 2.
2 Right Auricle.
3 Left Ventricle, with Left Auricle above.
4 Right Ventricle.
Pulm. Art. and Pulm. Veins.
(*pa* and *pv*, Fig. 15) visible.

Fig. 19.



Trachea, Bronchial Tubes and Left Lung.
a Larynx.
b Trachea.
c Right Bronchus.
d Small Bronchial Tubes.
e Minute Bronchial Tubes.
($\frac{1}{40}$ in. diameter).

divide and subdivide into a great number of smaller and smaller tubes (*d*), which penetrate to every part of the lungs. The trachea and bronchial tubes, owing to their cartilages, are unyielding, so as to remain permanently open; the finer tubes (*e*), about $\frac{1}{40}$ of an inch in diameter, have no cartilages; therefore, they may be closed by contraction. The minute portion of a lobe is called a *lobule;* a lobule is a little lung of itself. Each minute bronchial tube passes into a lobule. After entering the lobule, the small bronchial tube divides still further into smaller branches (Fig. 20), whose walls at length become exceedingly thin. Each such minute branch widens at its end into an *air-cell.*

Fig. 20.—Bronchial Tubes, with Air-Cells (magnified 15 times).

An air-cell, therefore, is a minute cavity of about $\frac{1}{40}$ of an inch in diameter (Fig. 21). The air-cells are arranged singly, or in groups so that a series of cells open into the same bronchial tube. The lungs are made up of air-cells. Each air-cell carries a network of capillaries—that is, of minute blood vessels (of about $\frac{1}{3000}$ inch diameter; this network is so dense that its open spaces, or meshes, are even narrower than the capillaries themselves. Between the air in the cells, then, and the blood in the capillaries are but two delicate membranes, that of the cells and that of the capillaries.

The purpose of this network of capillaries is to thoroughly expose the blood to the action of the air. This is accomplished, 1st, by spreading the blood over a large surface; 2d, spreading it in thin

Fig.21.

$\frac{300}{1}$

Fig. 21.—Air-Cell, with Capillaries.

streams; 3d, protecting it by merely a very delicate cover. The renewal of the blood in these capillaries is a result of the circulation; the renewal of the air in the cells is the result of *respiration.* The number of respirations is from fifteen to eighteen a minute, and varies slightly, according to the age of life.

Venous blood absorbs oxygen in the lungs through the membranes separating it from the air, while at the same time *it parts with carbonic acid gas and water vapor.* This influx of oxygen into, and efflux of carbonic acid gas and water-vapor out of, the blood form the most important part of the respiratory process. They purify the blood in changing it from venous into arterial, the means of purification being the peculiarly delicate membranes mentioned above.

(See also page 80.) But the action of the membranes alone would suffice only for a short time, since the carbonic acid gas accumulates very rapidly, and in large quantity; and also because oxygen is needed all over the system at every instant of time. Hence we need a rapid removal of the carbonic acid gas from the lungs, and at the same time an incessant importation of fresh oxygen. We find that the clearing away of the one and the supply of the other, are accomplished incessantly by the act of *inspiration* and *expiration.* The most powerful aids in this process are the elasticity of the lungs, the mobility of the sides of the chest, and the mobility of the diaphragm. The diaphragm is a strong muscle separating the chest from the abdomen, thus forming the floor of the chest. Its special business is to assist respiration.

To avoid chilling the lungs, coïd air should be inspired through the nasal passages; not through the mouth.

Read *Consumption:* Dr. C. Both. Lee & Shephard: New York.
Read Science Lectures—First Series. Heywood: Manchester.

LESSON XIX.

RESPIRATION.

The inspiration of air into the lungs is effected in this way: The lungs are in close contact with the inner side of the chest-walls; the lower portion of the lungs is in close contact with the diaphragm. It is evident that whenever the chest-walls move, the lungs must also move, and *vice versa*. So, when the chest expands the lungs expand; or, more properly speaking, they are enlarged by a quantity of air which rushes through the larynx, trachea and bronchi, to fill the lungs (compare First Lessons in Physics, Lesson XIX., p. 71).

In expiration the chest-walls contract; the lungs contract likewise—that is, a quantity of air is ejected from the lungs and forced to pass through the bronchi, trachea and larynx, this being the only communication between the lungs and the external air. The act of expiration is followed by a short rest.

The widening of the chest during inspiration is owing to the motion of the ribs; the lengthening of the chest during inspiration, to the descent of the diaphragm. *In ordinary inspiration* both chest and lungs return to the state of rest by their elasticity. Ordinary inspiration is nearly exclusively ef-

fected by the mobility of the diaphragm and the ribs. In very deep inspiration, the dimensions of the chest are increased still further by the ascent of the clavicle and the stretching of the vertebral column.

The rhythm observable in the respiratory process is inspiration, expiration, pause; that of the heart being, in a similar manner, auricular systole, ventricular systole, pause.

Inspired and expired air differ from each other chiefly in the following points:

(1.) Expired air has nearly the same temperature as the blood, whatever may be the temperature of the external air.

(2.) Expired air is always filled with water-vapor.

(3.) Expired air always contains more carbonic acid gas and less oxygen than inspired air. One hundred parts of air breathed once have lost about five parts of oxygen, and gained a little less than five parts of carbonic acid. This is shown by the following statement:

	Oxygen.	Nitrogen.	Carb. Acid.
10,000 parts of atmospheric air contain	2080	7916	4
10,000 parts of expired air contain (nearly)	1600	7916	484

The absorption of oxygen by the venous blood in the lungs is accomplished by the red blood corpuscles. Although separated from the oxygen by the thin walls of the air-cells, they seize upon the oxygen, attach themselves to it, and make it accompany them on their journey through the system. The activity of the oxygen is thus highly increased, and causes very important chemical changes in the body

as it unites with the carbon particles in the blood, gradually changing them into carbonic acid. This gas remains dissolved in the blood, giving the latter its dark-red color; but upon arriving in the lungs it is liberated, passes out as the oxygen passes in, and is removed by expiration.

Ventilation.—Since about four hundred cubic feet of air pass through the lungs of an adult in twenty-four hours, a constant supply of oxygen—that is, of fresh air—is one of the most essential requirements of health. And since carbonic acid gas is unfit for respiration, it follows that every inhabited room should have an open space to admit fresh air, and an open space to convey away the waste products of respiration; both spaces must directly or indirectly communicate with the atmosphere. But the presence of a surplus of carbonic acid is less injurious than the absence of the normal amount of oxygen. A person living in badly ventilated apartments vitiates his blood, predisposes his system to disease, and thus virtually shortens his life. A total lack of air would result in speedy death.

Coughing is a quick and forcible expiration or series of expirations; the glottis is closed, and a current of air is violently forced through it in the mouth. This causes the well-known sound accompanying coughing.

Sneezing is the same process, but with the cavity of the mouth closed, the forcibly ejected air passing through the nose.

Sighing consists of a slow, deep inspiration, followed by quick and short expiration.

Laughing is a rapid succession of short and forcible expirations, each accompanied by a ringing sound.

Sobbing is a series of abrupt, inspiratory acts, mostly produced by strong contractions of the diaphragm, and accompanied by sounding vibrations of the vocal chords.

Snoring results from the current of expired air striking against the soft palate, and causing it to vibrate.

Respiration by means of the skin.—Through the skin of the body oxygen of the air enters, and passes to the blood; and carbonic acid gas and water-vapor emerge through the skin from the body. The quantity of water-vapor perspired in twenty-four hours amounts to about $1\frac{3}{4}$ pounds. (Compare page 69.)

The proper supply of oxygen forms one of the three most important requirements for health. (For the remaining two see pp. 70 and 88.)

THE LUNGS AND THE HEART COMPARED.

Three points in common:

1. Both operate by expansion and contraction.

2. Both are involuntary organs; that is, on ordinary occasion they act independently of the will.

3. Both are indispensable to the maintenance of life.

Three points of difference:

1. The lungs contain air; the heart contains blood.

2. The lungs contain bronchial tubes, air-cells and blood-vessels; the heart has two parts, called the right and the left side, each part being again divided into auricle and ventricle.

3. The lungs purify the blood; the heart propels the blood through the body.

Read *Cough and Colds.* Hurd & Houghton: New York.

Read *Ventilation.* Popular Science Monthly, Vol. I., p. 356.

LESSON XX.—REVIEW.

LESSON XVIII.—

1. There are two kinds of blood, the arterial and venous. The main difference between them is, that the latter contains less oxygen but more carbonic acid gas than the former.

2. Venous blood passes from the system to the heart, and from the heart to the lungs; arterial, from the lungs to the heart, and from the heart to the system.

3. The lungs consist of (1) the left lung, and (2) the right lung. The former has two and the latter three lobes.

4. Each lung is attached to a bronchus, each of which is again subdivided into a great number of smaller branches, called *bronchial tubes*.

5. An air-cell is a cavity or the dilated end of a minute bronchial tube, and about $\frac{1}{40}$ of an inch in diameter. The lungs are made up of air-cells.

6. The capillaries in the lungs serve to expose the blood to the action of the air. This is done by (1) spreading it over a large surface, (2) spreading it in thin streams, (3) protecting it by merely a delicate cover.

7. The renewal of the blood in these capillaries is a result of the circulation; the renewal of the air in the cells is the result of respiration.

8 The influx of oxygen into, and the efflux of carbonic acid gas and water-vapor out of, the blood form the most important part of respiration.

9. The act of inspiration supplies the lungs with fresh oxygen; that of expiration removes carbonic acid gas and water-vapor from them.

LESSON XIX.—

10. In inspiration a quantity of air rushes through the larynx, trachea and bronchi, and passes into the lungs, expanding and filling them.

11. In expiration, a quantity of air is ejected from the lungs by means of compression, and passes through the bronchi, trachea and larynx into the external air.

12. The rhythm observable in the respiratory process is inspiration, expiration, pause.

13. Inspired and expired air compared:

(1.) Expired air has nearly the same temperature as the blood, whatever be the temperature of the external air.

(2.) Expired air is always filled with water-vapor.

(3.) Expired air always contains more carbonic acid gas and less oxygen than inspired air.

14. *Coughing* is a quick and forcible expiration, or series of expirations.

Sneezing is the same process with the mouth closed.

Sighing is a slow, deep inspiration followed by a quick and short expiration.

Laughing is a rapid succession of short and forcible expirations, each accompanied by a ringing sound.

Sobbing is a series of abrupt, inspiratory acts.

Snoring results from the current of expired air striking against the soft palate, causing it to vibrate.

15. The proper supply of oxygen forms one of the three most important requirements for health. (For the other two compare pp. 55, 88.)

16. The lungs and the heart compared.

Three points in common:

(1.) Both operate by expansion and contraction.

(2.) Both are involuntary organs; that is, on ordinary occasion they act independently of the will.

(3.) Both are indispensable to the maintenance of life.

Three points of difference:

(1.) The lungs contain air; the heart contains blood.

(2.) The lungs contain bronchial tubes, air-cells and blood-vessels; the heart has two parts, called the right and left side, each part being again divided into auricle and ventricle.

(3.) The lungs purify the blood; the heart propels the blood through the body.

LESSON XXI.

AIR, AND ITS RELATION TO THE HUMAN BODY.—I.

Wherever man sojourns, whether within doors or out, whether below, above, or at the surface of the earth, he requires, night and day, an incessant supply of air, which he mainly uses for food, and as a means of cooling the body.

(Our atmospheric air is a mixture of two gases—nitrogen and oxygen; only the latter is available for food; nitrogen is not utilized for the purpose by the blood. Oxygen forms one-fifth of any given volume of the atmosphere; nitrogen, the remaining four-fifths.)

This Lesson treats of air as a means of cooling the body.

The human body, in order to properly carry on the functions of life, requires a *constant* internal temperature, which, in summer and winter, must be the same. Experiments have shown this temperature to be between 98° and 100° F.; and, as it does not vary under ordinary circumstances, this *vital* or *animal* heat, as it is called, must be generated in and distributed through the interior of the body at every instant of time. In severe cold weather the temperature of the air may be so low that one's ears or finger-ends may be cooled a few degrees below 98°, or even congeal; but the temperature of the

interior organs and of the blood remains unchanged. Should the cold be very intense, however, and affect the body continuously, then the temperature of the blood will be reduced, and the consequences be fatal. A decrease of five degrees below the normal standard of temperature will cause the vital processes to cease.

An increase in the temperature of the blood is always associated with a diseased state of the body, and if not overcome, in course of time, will prove fatal. Such an increase occurs in typhoid fever, often to the extent of eight degrees F.

A temperature not varying more than one degree from 99° F., whatever be the temperature of the surrounding air, is one of the three most important requirements for health.

It is obvious that the maintenance of the standard temperature of the body must be one of our main cares. Heat may be lost—I., by *conduction;* II., by *radiation;* and III., by *evaporation.*

I. Loss of heat by conduction.

10. Experiment.—The end of a wire held in a flame has a higher temperature than its nearest part outside the flame, while the end of the wire which is held in the hand is comparatively cool. We say now that the wire is unequally hot; and because of this inequality of temperature, the heat commences to pass from the hotter to the colder portions of the wire, so that, finally, the hand can no longer hold it.

In the same manner the human body transfers heat to any substance in contact with it and colder than itself, such as air, water or clothing.

The passage of heat from hotter to colder portions of a body, or from hotter to colder adjacent bodies, is called the conduction of heat.

If, by way of experiment, we were to step from a heated room suddenly into an apartment whose temperature was 32° F., a great deal of heat would be conducted away from the body, and the loss would at once be seriously felt; but were we, in a heated state, to plunge into ice-cold water, the loss of heat would be far greater—that is, the water would take more heat from the body than the air, and we should be chilled instantaneously. This shows that water is a better conductor of heat than air (compare First Lessons in Physics, pp. 94, 95). It also explains why we take cold more easily in moist and cold weather, than in dry and cold.

II. Loss of heat by radiation.

Familiar Facts.—On a bright and calm day in winter we feel the sun's rays to be quite warm, although the water on the ground be freezing, and the ice be dry and hard. The thermometer indicates a temperature below the freezing point, but when the direct rays of the sun fall on it, it rises at once, indicating a far higher temperature. This shows that the sun's rays pass through the air without heating it, but that they heat any object, such as a solid body, which stops them.

This passage of heat-rays from one body to an-

other without affecting the air through which they pass is called the radiation of heat. It differs from conduction, inasmuch as the radiating body is not in contact with the body heated, while conduction means the passage of heat from hotter to colder parts of the same substance, or of adjacent bodies.

On a cold day, if a person is seated by a window in a warm room, his loss of heat by radiation is only partial, and, therefore, more dangerous than an equal radiation from all parts of his body, such as takes place when he is walking out of doors. A partial radiation may produce a cold, and, if continued, entail serious injuries upon the system.

As the human body heats the air around it by conduction, and as warm air has less specific weight than cold air, currents of warmed air continuously ascend along the body. These currents are interfered with by the atmosphere, which constantly penetrates to the body, becomes heated at its expense, and thus exerts a cooling influence upon it. Hence, we feel colder when windy weather sets in, although the thermometer shows no reduction of temperature.

All bodies continually tend to equalize their temperatures by the diffusion of heat. This diffusion takes place by conduction and radiation.

III. Loss of heat by evaporation.

Familiar Facts.—A few drops of alcohol or ether, placed upon the bulb of a thermometer, will rapidly evaporate; this causes an immediate reduction of temperature, which is indicated by the ther-

mometer. So, snow and ice, when melting on the ground, reduce the temperature of the air.

Now, evaporation means the conversion of a liquid into the gaseous state. The conversion of solids into the liquid (or gaseous) state is called melting or fusion.

Whenever substances evaporate or melt, they absorb heat; this heat is taken from the adjacent body, and this body is thereby chilled.

In the case of the alcohol, the heat was given to it by the thermometer; in the case of snow and ice melting on the ground, the heat was communicated by the air. Both, the thermometer and the air, under those circumstances suffered a loss of heat; this is the reason why the thermometer sank, and the air became chilled.

The injurious effects of 'wet feet,' and of garments moistened from rain, or from having been worn next to the skin too long, are due to the cold produced by evaporation, and also to the greater conductive power of water. The skin must be kept warm, and free from moisture; garments worn next to the skin should be frequently changed. A person who, with his body heated from exertion or rapid motion, and perspiring copiously, should enter a colder atmosphere, or be exposed to a draught, would lose an enormous quantity of heat, both by conduction and radiation.

Diseases resulting from 'colds' are among the most painful and dangerous. The process of 'cooling off' should at all times be carried on slowly and gradually.

LESSON XXII.

AIR, AND ITS RELATION TO THE HUMAN BODY.—II.

The normal temperature of the body should be maintained at all times, whether the temperature of the atmosphere be low or not. This is effected (1) by clothing, (2) by the bed, (3) by buildings.

1. *Clothing.*—Our garments act like so many artificial skins, and thereby protect the skin from the injury which would result to it were it left exposed to the changing habits of our climate. They lose heat in place of the skin; they sustain intense cold or heat, rain and storm, in order that the delicate vessel of the skin may not be contracted by cold or expanded by heat, and its nerves not be shocked. But it is not desirable to shut out the atmosphere altogether from the body, else we might wear a tight fitting India-rubber suit, or one of kid-leather. In either of these the exhalation of the skin (Lesson XIII.) would be impeded, which would be followed by dangerous consequences. Besides, close-fitting garments are productive of cold, because they do not envelop a sufficient quantity of air; this may be well shown by wearing kid gloves in a cold atmosphere. India-rubber offers excellent

shelter from storm and moisture, but it must not form an habitual garment, because it is impervious to air. Flannel permits a hundred times as much air to pass through its tissues as fine leather, yet it is very much warmer than either leather or India-rubber.

The body heats the air around it; the air thus heated heats the garments, which should retain most of this heated air. The first purpose of clothing, therefore, physiologically considered, must be to retard the outward diffusion of heat, by radiation and conduction, from the body.

Radiation, however, may be prevented by a single cover. This is the case with the earth. In clear nights the earth radiates its heat out into space; this radiation produces a low temperature on its surface, which, under the tropics, becomes fatal to travelers sleeping out of doors. In cloudy nights, however, the clouds act as a screen; the heat radiated from the earth is, in great part, reflected back to it.

If, in our latitudes, we wore a single garment, though protecting us from the effects of radiation, it would be powerless against losses by conduction. The outer, colder air, would constantly traverse it, cool the layer of heated air around the body, strike the skin and there warm itself at the expense of the delicate nerves and vessels of the skin.

The second purpose of clothing, therefore, must be to retard the inward motion of currents of outer, colder air.

From the preceding it is obvious that a regular succession of garments is necessary; that they, as well as the air which they contain within their meshes, grow colder as their distance from the body increases; and that garments generally (more especially the outside garments, as an overcoat,) carry on upon their surface the equalization of temperature between the outer, colder, air and the heated atmosphere within, in order that it may not take place on the surface of the skin.

As the garments worn next to the skin are constantly moistened by perspiration, their water-absorbing qualities should be consulted. And since moist fabrics are better conductors of heat than dry ones, such garments must be frequently changed.

Linen is a rapid absorbent of moisture. As the moisture absorbed readily evaporates, and thereby produces cold, and as linen is also a good conductor of heat, it is a favorite article of clothing in summer; but it should never be worn next to the skin.

Cotton neither absorbs as much moisture, nor conducts heat as well, as linen. It is, therefore, warmer, although much cooler than either wool or silk.

Woolen is a great absorbent, which does not give up its moisture so readily as the preceding fabrics. This property makes it very valuable. It is a bad conductor on account of the great quantity of air contained within its meshes. It also possesses

the property of condensing water-vapor within its tissue, and thus produces warmth. This explains why fresh flannel, put on after great exertion, feels so warm. It should at all times be worn next to the skin.

2. *The bed.*—This is the sleeping apparel during nearly one-half of our life, and as important as clothing. It is made of material similar to that of garments and serves the same purpose. But it must be made much warmer than our clothing, because (1) the body develops less heat during sleep, and must yet be maintained at its standard temperature; (2) the body, when not lying down, is heated by currents of heated air ascending from the feet to the neck, while when stretched out horizontally the body is not so heated, for these currents then ascend perpendicularly from the body.

3. *Buildings.—Dwelling houses* serve the same purposes as clothing, which they also resemble in this: that, as a rule, they are built of badly conducting material. Like clothing, the walls of buildings should always be permeable to air. As long as they are in good condition they are easily penetrated by atmospheric currents. This is evident, for we know that wood, brick and stone are more or less porous, and that they readily absorb water; now, wherever water can penetrate, air, being so much lighter, can enter in hundredfold quantities; the fact that we never feel air pass through walls means nothing, since currents of air moving at a rate less than about 20 inches a second are not felt by the nerves.

Moist walls are unhealthy for the same reasons as those applying to moist garments: (1) the stoppage of ventilation, the pores of the walls being taken up by water to the exclusion of air; (2) the cold-producing effects, owing to increased radiation and conduction to heat the water; (3) the cold generated by the evaporation of the moisture.

Large quantities of water are contained in the mortar of the walls in newly erected buildings. Most of this water must be first removed before the dwelling is fit to be inhabited. It is removed best by giving it sufficient time to evaporate, and promoting the evaporation by means of artificial heat and by removing the vapor by ventilation.

Pure air is essential to health. Atmospheric air depends for its purity on being washed by rain and dew. It is heated and dried by the sun, fed with oxygen by plants and by them also freed of carbonic acid gas. Impure air may result from (1) the want of sunlight; (2) the want of cleanliness in the household; (3) the absence of efficient ventilation; (4) the presence of dust, smoke or decaying matter. It is very dangerous to the lungs, and although its pernicious effects upon the health are generally slow, they are nevertheless sure.

Ventilation and draught may now be better understood. Ventilation is the imperceptible efflux of impure air and the simultaneous imperceptible ininflux of atmospheric air. It depends—(1) Upon the difference of temperature between in-doors and out. Thus, in severe cold weather, a room, to be well ven-

tilated, must be heated. (2) The quantity of motion of the atmospheric air. Strong currents of air, as winds or storms, greatly facilitate ventilation. (3) The size of the orifices through which the air is expected to pass. When No. (1) fails, as e. g., in summer, we use No. (3) mostly—that is, we open doors and windows.

Draught is a *perceptible current* of *colder air* striking, and consequently cooling, only a portion of the body.

Read *The Bazar Book of Health* (The Dwelling, &c). Harpers.
Disease Germs. L. S. Beale. Lindsay & Blakiston, Phila.
Thermic Fever, or Sunstroke. Lippincott, Phila.

LESSON XXIII.—REVIEW.

LESSON XXI.—

1. The human body, in order to properly carry on the functions of life, requires a *constant* internal temperature.

2. A reduction or increase of the standard temperature may, if continued, prove fatal to life.

3. A constant temperature of very nearly 100° F., whatever be the temperature of the surrounding air, is one of the three most important requirements of health. (For the other two, see Lessons XIV. and XIX.)

4. This temperature is maintained by interior functions of the body.

5. All bodies continually tend to equalize their temperatures by the diffusion of heat. This diffusion takes place by conduction and radiation.

6. Whenever substances evaporate or melt, they absorb heat; this heat is taken from the adjacent body, and this body is thereby chilled.

7. The human body, as is seen from 5 and 6, loses heat in three ways: (1) by conduction, (2) by radiation, (3) by evaporation.

LESSON XXII.—

8. The heat of the body is retained by clothing, the bed and buildings.

9. Clothing protects the delicate vessels and nerves of the skin from the effects of intense cold or heat. They should include and contain air, because air is a bad conductor of either heat or cold.

10. Clothing (1) retards the outward diffusion of heat (by radiation and conduction) from the body; (2) it retards the inward motion of currents of outer colder air.

11. The bed must be warmer than one's garments, because (1) the body develops less heat during sleep, and must yet maintain its standard temperature; (2) the body, when in a horizontal position, is not heated by currents of heated air ascending along it.

12. The walls of buildings should be permeable to air, the same as clothing.

13. Moist walls are pernicious to health, because (1) of the stoppage of ventilation, the pores of the walls being taken up by water to the exclusion of air; (2) of the cold-producing effects, owing to increased radiation and conduction to heat the water; (3) of the cold generated by the evaporation of the moisture.

14. The moisture in the walls of newly erected buildings is best removed by giving it sufficient time to evaporate, by promoting its evaporation by

means of artificial heat, and by removing the water-vapor by ventilation.

15. Pure air is essential to health. Our atmosphere is washed by rain and dew. It is heated and dried by the sun; it is fed with oxygen by plants, and freed by them of carbonic acid gas.

16. Impure air may result (1) from the want of sunlight; (2) the want of cleanliness in the household; (3) the absence of efficient ventilation; (4) the presence of dust, smoke, or decaying matter.

17. Ventilation is the imperceptible efflux of impure air, and the simultaneous imperceptible influx of atmospheric air.

18. Draught is a perceptible current of colder air striking only a portion of the body.

LESSON XXIV.

FOOD.

11. EXPERIMENT.—*Hydrogen* gas may be liberated from muriatic acid poured on a little zinc or on a nail in a test-tube. The gas is recognized by its burning with a pale, bluish flame. By connecting the mouth of the test-tube with a suitable tube, the gas may be conducted into a tumbler filled with and inverted over water.

12. EXPERIMENT.—*Oxygen* gas may be liberated from an ounce of pulverized potassium-chlorate mixed with a like quantity of manganese dioxide, by placing the mixture in a test-tube and applying heat. It may be recognized by its rekindling a glowing taper; like hydrogen, it is easily caught in an inverted tumbler.

13. EXPERIMENT.—*Nitrogen* gas may be obtained from common air by burning a short piece of candle, fastened on a fragment of board so as to float on water, and inverting a glass jar over the candle. The light will be extinguished, some water will rise into the jar, and nearly all the remaining gas will be nitrogen.

Carbon may be represented by a piece of coke or charcoal.

Hydrogen, *oxygen*, *nitrogen*—three gases—and *carbon*—a solid—are the principal elementary substances which, when combined with each other, form the materials composing the human body.

The functions of the human system cause a waste of tissues. This waste must be repaired or the individual will die. Since the human body is composed of combinations of carbon, hydrogen, oxygen and nitrogen, it must be repaired by a supply of aliments containing these materials. When an or-

ganism is deprived of proper food it commences to feed upon itself.

Waste of tissue arises from the incessant work which the body performs, consisting of mechanical motion, as when a person is walking, or a blacksmith strikes a piece of iron on the anvil; or of vital functions, such as breathing and digesting; or of mental processes, as when one is thinking and studying. All such work diminishes the weight of the organism; and if the labor were continued without food being taken to repair the waste, the result would be death. For a further illustration, suppose that a man who has been carefully weighed, be placed in a glass house containing cold and dry atmospheric air, and told to walk up and down in it for an hour without interruption. At the end of that hour, if he be weighed again, he will be found to have lost in weight. This loss is balanced by the amount of work he has done, viz.: 1. The mechanical labor in lifting and moving the weight of his body at every step. 2. The rise in temperature, indicated by a thermometer hung up inside of the glass house, which shows that he has heated the air around him. 3. The moisture on the inner sides of the glass, due to expiration. 4. Carbonic acid gas, also due to expiration, the presence of which is shown by a white film of carbonate of lime on the limewater in a vessel placed on the floor of the glass house.

Food, generally speaking, is any substance adapted to supply the body with material that renews lost tissue or supports some process of life. It

is divided into organic and inorganic materials. Organic food comprises (1) nitrogenous substances, such as meat, milk, or white of an egg; (2) fats, such as butter or lard; (3) compounds of carbon and hydrogen, such as starch or sugar. The last two classes, when pure, contain no nitrogen. Inorganic food comprises water, the most important article of food, and alkalies, such as salt and phosphates. No single class is generally considered sufficient; all of them are necessary to make food nutritive and convenient; a man feeding entirely upon bread and sugar may ultimately be starved as surely as one whose diet is composed solely of meat, or of mineral water. Intuitively, we eat bread and meat, or bread and cheese, bacon and beans, stuffing and fowl. Persons who live largely on meat prefer it fat; those who feed mostly on vegetables consume a great deal of milk, because milk contains the three classes of organic food, as well as inorganic materials.

Oxygen is an article of food, as it serves to maintain important vital functions. It is the only article of food which enters the system as a simple or elementary body; all the others are compounds.

Digestibility of Food.—A substance may be highly nutritious, but if its consistency is so great that it is insoluble in the digestive fluids, it is useless as nourishment. This is the case with bones and cartilages. Tasteless substances, such as common oil, do not digest, because they fail to produce secretion of saliva, an essential element in the preparation of food. Many articles of food are ren-

dered nutritious by condiments, which, without these, might not even have been palatable. Tea, coffee and juices must be regarded as great helpers to nutrition; so also a frequent change of, and variety in, our bill of fare.

Irregularity in diet is a frequent cause of disease. Next to it, perhaps, stands the want of the proper preparation of food by cooking. The purpose of cooking is: (1) to soften the food; (2) to give it an agreeable favor. Beans, grains and many kinds of fruit can not be digested in a raw state.

Hunger and Thirst.—The man whom we supposed to take exercise in a glass-house would dwindle to nothing in due course of time unless he took food to repair his waste. The imperious sensations which remind us forcibly of the want of solid and liquid aliment are hunger and thirst. To satisfy the former, the body must be supplied with solid food; to satisfy the latter, with water in some shape or other.

Solid Food.—Over the whole world beef is justly considered the most nutritious kind of flesh. Its flavor is fuller and more attractive than that of other meats, and, as it has a denser structure, the volume of beef required for a meal need not be as large as that of other kinds of flesh. *Veal* is inferior to beef, as it is more difficult to digest. *Mutton*, although a lighter food than beef, is more suited to persons who take little exercise. *Pork* is less nourishing than either beef or mutton. It is commonly believed to be less digestible, and scientists have found that it requires more time for digestion. Ham is more nearly like beef, as it contains less fat than the other parts of the pig. Pork is known to be more frequently diseased than other meats. Its use is most extensive in new countries on account of the facility in raising pigs, in preserving the meat, and also on account of the difficulty in having a sufficient demand in thinly-settled districts for a freshly-slaughtered ox or sheep. *Fish* should never

take the place of beef permanently, but rather play the part of an agreeable companion to, or variety of, other animal food. The nutritive qualities of red-blood fish, as the salmon, are nearly as great as those of any other red-blood flesh, while white fish is less nutritive. *Butter* depends for its flavor very much upon the food of the animal from which it is derived. As lean meat serves principally to produce and maintain the structures of the body, the fats—and they include butter—mainly generate by their oxidation the heat required for the vital processes.

Wheaten flour and bread are "the most important vegetable production of temperate climates — that upon which the life of man in these regions mainly depends. Its importance rests upon several properties, by which it is acceptable and good food for all ages and classes of the people. It is produced abundantly and cheaply; is easily ground and refined; is readily and thoroughly cooked; has a mild flavor which is universally agreeable, and contains nearly all the essential elements of nutrition. It is preferable to any of the other great vegetable products on which men chiefly live, since it is a far more agreeable food than maize, and a more nutritious food than rice. It is probable that the health and mental and bodily vigor of the inhabitants of temperate climes are more attributable to this food than to any other single cause." *Potatoes* can not be used alone, as they lack mineral elements; about three pounds of potatoes are equivalent to one pound of bread as regards nutritive contents.

Liquid Food. — *Water* is, of all foods, whether liquid, solid or gaseous, the most important. It forms about 87 per cent. of the human body. Lean beef contains nearly 72 per cent. of water, veal 63, mutton 72, fat pork 40, poultry 73, fish 75, wheaten bread 37, coffee and tea nearly 100. To be good to the taste it must contain, as it nearly always does, a small quantity of atmospheric air. Mineral matters in water render it hard; for domestic purposes it is rendered soft by boiling, or by treatment with lime, soda or ammonia. Organic matter in water is harmless when existing in very minute quantities; if otherwise, it is very injurious to the system and a frequent source of disease. Turbid water from wells is impure, while the turbidity of water from streams simply arising from sand or the soil is quite harmless. Water infected with organic matter, or offensive to the smell or taste, must be rejected. *Milk* contains all the nutritive elements, and is readily digested. *Tea* is an infusion of the leaves of the tea-plant, of scarcely any nutritive quality, but highly valued as a means of exciting vital processes and stimulating respiration as well as perspiration. *Coffee* is probably as little nutritious as tea; like this, it stimulates respiration, but, unlike tea, it tends to make the skin dry.

LESSON XXV.

DIGESTION.—I.

[Before studying this Lesson review "Teeth," Lesson III.]

The food of plants requires no modification previous to its being absorbed by the vegetable organism. Plants feed principally on water, carbonic acid, ammonia, and saline substances, all of which they find ready for their absorption. Man and animals, however, derive their food principally from organic substances. They prepare it within their bodies before it is absorbed by the blood; and man, in addition, cooks his food.

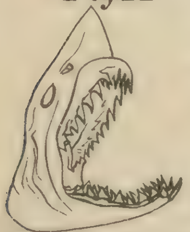
The changes wrought upon the food in the body may be divided into three parts: 1. Digestion, or the proper preparation of food in the alimentary canal (Lesson III.), so as to fit it for absorption. 2. Assimilation, or the conversion of food into blood and tissue. 3. Excretion, or the decomposition of food and its removal from the body. With the exception of the lungs, which absorb oxygen, the alimentary canal is (generally) the only channel by which food can pass into the blood.

The quantity of food—dry, solid and nutritious—daily introduced into the mouth of a man of average size and activity, is about 35 ounces, to which must be added about a pound of oxygen gas absorbed by the lungs, making in all a little over

three pounds. To this should be added the oxygen which, during insalivation, mingles with the food.

Digestion commences immediately upon the passage of food into the mouth before entering the stomach. Solid food must first be crushed by the action of the teeth, jaws and tongue. This part of digestion is called *Mastication.*.

Fig.22



Jaws of a Fish.

While the structure of teeth belongs to Lesson III., it may be interesting here to refer to the adaptation of teeth in different classes of animals to the food upon which the animal subsists. Thus, in fish, the food is swallowed entire; hence, the teeth have, as a rule, the form of sharp, curved spines (Fig. 22). Such teeth merely serve the purpose of retaining or holding the prey. The

Fig.23.

Skull of a Horse.

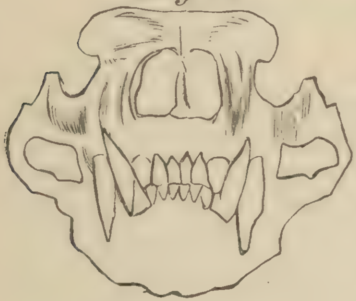
horse has incisors in both jaws (Fig. 23), while herbivorous animals of the ruminating order have their

incisors only in the lower jaw. These incisors merely serve to cut off the grass or herbs upon which the animal feeds. The process of mastication is performed entirely by the molars, the canines being either wanting or only imperfectly developed. Carnivorous animals, such as the bear or dog, have incisors for dividing the food, canine teeth for attacking and retaining the prey, and molars for grinding (Fig. 24). In man the teeth are so selected as to combine the features of those of the herbivorous and the carnivorous animals, which distinctly points to the fact that his food should be composed both of animal and vegetable substances. The tongue has the function of holding back the portion of aliment which is about to pass down not yet wholly crushed by the teeth; and any particles of food which have been pushed outside of the teeth are thrust back again under the teeth by the compression of the lips and cheeks. The tongue also crushes soft substances against the palate. It is, at the same time, an organ invested with special mobility and acute sensibility, so as to pass judgment upon the qualities, situation and degree of trituration of the aliment in the mouth. The combined action of the teeth, tongue, lips and cheeks results in the breaking down of the food. The purpose of this is, that the food shall present a large surface to the dissolving action of the various fluids acting upon it. If large masses were to pass down unbroken by the teeth, they would scarcely be altered in the stomach, and consequently, supply nutrition imperfectly. For this and other reasons,

rapid eating should be studiously avoided; it frequently causes indigestion.

Insalivation, the second part of digestion, takes place in the mouth. It is here that the masticated food thoroughly mixes with the saliva of the mouth, abundantly secreted from a number of salivary glands, and, at the same time, mingles with air, which is contained in the bubbles of the saliva. This liquid contains over 990 parts of water in 1,000 parts of its weight. It changes a large portion of the starch, which the food may contain, into sugar.

Fig.24.



Skull of a Polar Bear.

Deglutition, or the act of swallowing—the third part of digestion—takes place after the aliment, by means of mastication and insalivation, has been reduced to a minute pulp, and transferred from the mouth through the œsophagus or gullet, to the stomach. This downward passage is effected by a successive contraction of the muscular parts around the œsophagus above the food, while they are lax below. Hence it is that a man can drink standing on his head; and a horse with its head lower than its stomach. Food, while in the mouth, is controlled by the will, but deglutition is not.

LESSON XXVI.

DIGESTION.—II.

Digestion in the stomach is the fourth part of digestion. The stomach (Fig. 25, p. 114) is the continuation of the gullet, but it is much wider, and of different forms in different animals. It is a sort of bag of about one and a quarter square feet internal surface, with a capacity of five pints, and a weight of seven ounces, in the adult man. It has two openings—one (*a*) to admit food, called Cardia, and which is always open; the other (*b*), called Pylorus, which, during stomach digestion, is firmly closed so as to allow only the finest pulp to pass. On the outside the bag consists of a thin membrane, next to which is a muscular coat, forming the center; and of a mucous layer, which forms the inner lining of the substance of the bag. The muscular coat is made up of involuntary muscles; it is these which perform the mechanical labor of kneading and rolling about the pulp. The food is pushed on along the great curvature of the stomach (on the left side of the body) to the right, and thence to the left along the lesser curvature. The continual rolling motion, together with the continual addition of gastric juice, finally reduces the food to a fine pulp of a consistency somewhat like that of a thick soup, which is called *chyme*. The stomach is not capable of great

muscular effort; hence, it can not crush, e. g. an entire grape. The violence of abdominal motion in vomiting is not due to the effort of the stomach alone, but to the co-operation of abdominal muscles.

Chief functions of the stomach: (1) to mix all food into a pulp; (2) to dissolve the nitrogenous portion of the food by means of the gastric juice (see next Lesson). The conversion of starch into sugar, which takes place in the mouth, is in the stomach discontinued temporarily, but not suspended, as will be seen further on. (Regarding absorption in the stomach, see the next Lesson.)

Conditions favorable to stomach digestion. The following are among the most important: 1. A temperature of 100° F., nearly. Any reduction, such as results from overdoses of water or ice cream, may lead to serious results. When a substance, instead of being digested in the stomach, is digested in the intestines, the time required is vastly greater.

2. Continual motion of the walls of the stomach to permeate the food with gastric juice.

3. The removal of such portions of the food as are thoroughly digested. This brings the remainder into better contact with the gastric fluid.

4. Perfect mastication and insalivation of the aliment previous to its entrance into the stomach.

5. A moderate quantity of food. The stomach should not be distended.

6. Regular intervals between any two consecutive meals. They should be long enough for the food of one meal to have left the stomach before the next is introduced.

7. No severe physical or mental exertion either immediately before or after a meal.

8. A tranquil mind. 9. Bodily health.

10. Favorable weather.

The processes which the food has undergone between its first introduction into the mouth and its removal from the stomach through the pylorus are: (1) mastication, (2) insalivation, (3) deglutition, (4) digestion in the stomach.

The changes wrought upon the food by these processes should now be carefully reviewed. What happens to the food in the stomach will be explained in the next Lesson.

"According to the experiments of Dr. Beaumont, liquid substances are, for the most part, absorbed by the vessels of the stomach at once, and any solid matter suspended in them, as in soup, are concentrated into a thicker material before the gastric juice operates upon them. Solid matters are affected so rapidly during health that a full meal, consisting of animal and vegetable substances, may be converted into chyme in about an hour, and the stomach left empty in two hours and a half. Dr. B. found that among the substances most quickly digested were rice and tripe, both of which were digested in an hour. Eggs, salmon, trout and venison were digested in an hour and a half; tapioca, barley, milk, liver and fish in two hours; turkey, lamb and pork in two hours and a half. Beef, mutton and fowls required from three to three and a half hours, and these were more digestible than veal. These facts were different from what was anticipated, and show that prevailing notions as to the digestibility of different kinds of food are very erroneous. It must be remembered, however, that easy digestibility does not imply high nutritive power. A substance may be nutritious, though so hard as not to be readily broken down; and many soft, easily digested materials may contain a comparatively small amount of nutriment."—J. H. Bennett. Physiology. Lippincott & Co., Phila.

Read *Dyspepsia*. By E. P. Miller. Miller, Haynes & Co., N. Y.

LESSON XXVII.

DIGESTION.—III.

Digestion in the intestines—the fifth part of the process of digestion. The *intestines* (Fig. 25) are the continuation of the stomach. They form a long, narrow tube, which, like the stomach, is composed of membranous, muscular and mucous coats. The intestines are of different length in different orders of animals. They are divided into two parts, viz., the *small intestine* and the *large intestine*.

The *small intestine* is subdivided into the *duodenum*, D, and the *small intestine proper*, Dp. The order in which they follow each other is, (1) the stomach, (2) the duodenum, (3) the small intestine proper, (4) the large intestine.

The *alimentary canal* begins with the mouth and terminates with the rectum. Its entire length is 400 inches, nearly, of which about 240 inches belong to the small intestine. The small intestine has many windings, is indirectly attached to the spinal column, and fills the lower central portion of the ventral cavity.

The small intestine possesses a regular motion in the direction of its own course; this motion is called *peristaltic*, and consists of muscular contractions, such as take place in the gullet, the purpose of

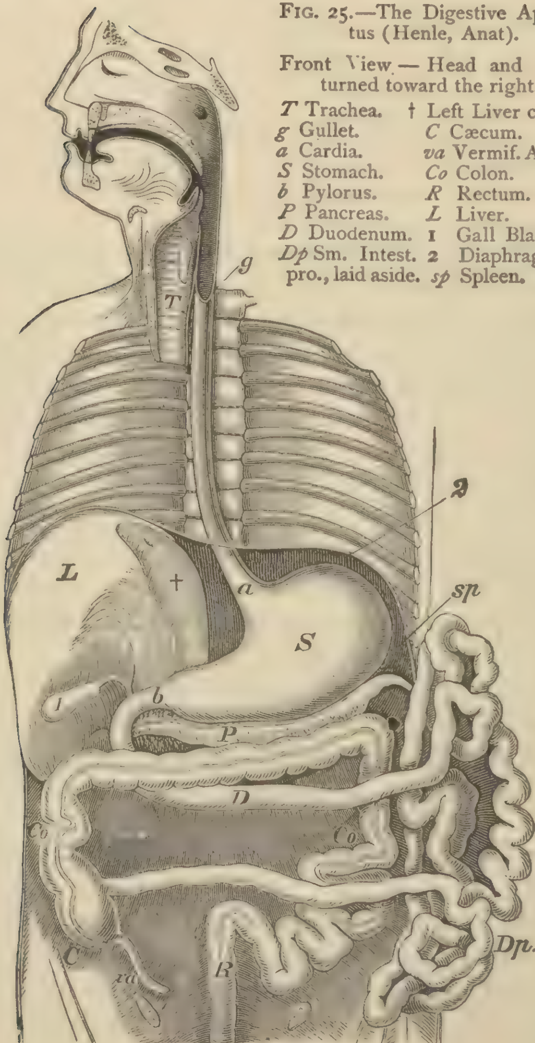


FIG. 25.—The Digestive Apparatus (Henle, Anat).

Front View — Head and Neck turned toward the right.

T Trachea.	† Left Liver cut off.
g Gullet.	*C* Cæcum.
a Cardia.	*va* Vermif. Appen.
S Stomach.	*Co* Colon.
b Pylorus.	*R* Rectum.
P Pancreas.	*L* Liver.
D Duodenum.	1 Gall Bladder.
Dp Sm. Intest. pro., laid aside.	2 Diaphragm.
	sp Spleen.

which is, to propel the food onward to the lower parts and into the large intestine.

The *large intestine*, about five feet long, is shorter but wider than the small intestine. It has three subdivisions: the *cæcum*, C, the *colon*, Co, and the *rectum*, R. The cæcum is the short portion below the junction of the small intestine, and distinguishable by a vermiform appendix, *v*, *a*, about three inches in length. The continuation of the cæcum forms the colon, which rises on the right side of the abdomen up to the liver. This portion of it is the *ascending colon*. The colon then suddenly turns at a right angle and crosses over to the left side of the body; this horizontal part of it is called the *transverse colon;* finally, it makes a sudden turn downward and backward along the left side of the body, where, accordingly, it is called the *descending colon*, which is succeeded by the rectum, R. The large intestine is readily recognized by its width, its stretching capacity and its many folds and pouches. Its motions are far slower than those of the other intestine, and scarcely ever result in actual displacements of the parts with reference to each other, such as take place in the small intestine.

DIGESTIVE FLUIDS.

1. The *saliva*, the action of which was explained on page 109.

2. The *gastric juice*. The interior coat of the stomach contains a great number of glands which are open upon its surface. Some of these are in the

vicinity of the pylorus, and secrete a mucous substance which covers the interior surface of the stomach, and serves to envelop undigested pieces of food so as to facilitate their passage through the intestines. The others, which form by far the greater number, secrete a clear acid liquid, the *gastric juice.* This fluid has an extraordinary solvent power on albuminous and other substances; one part of it in 60,000 parts of water will be sufficient to exert this power. It does not act upon fatty substances further than liquefying them. It is readily precipitated by alcohol; this may explain the pernicious effect upon the stomach, caused by the use of alcoholic drinks. The churning motion of the stomach, together with the solvent action of the gastric juice, reduces the food to *chyme*, which passes through the pylorus into the duodenum, and is shortly afterward mixed with bile and pancreatic juice. The stomach is the part in which the food undergoes its most important change.

3. *The Bile* is a brownish-yellow, very bitter liquid secreted by the liver (L, Fig. 25). The liver is the largest gland in the body; it weighs from 50 to 60 ounces, has a dark-red color, and lies on the right side of the body. Its upper part is connected with the diaphragm, its lower touches the intestines. The liver (1) secretes bile, and (2) modifies sugar for purposes which this has to serve. The bile accumulates in a reservoir, called the gall-bladder, from which, whenever the duodenum is distended by chyme coming from the stomach, it flows into the duodenum, to mingle with the chyme. Bile

contains waste materials which it has taken from the blood; it must, therefore, be conducted out of the system. If prevented from entering the duodenum, it congregates in the blood, producing jaundice, and acting then as a poison. Should some of it happen to be thrown into the stomach, digestion there would cease at once; nausea and vomiting, the usual bilious symptoms, would occur. It acts also as a solvent of the fatty portions of food, and as a stimulant to the action of the intestines. Chyme, after its union with bile, is usually called *chyle*.

Chyme, as it leaves the stomach, is composed of—

(1) Albuminous matter, broken down, partly dissolved, partly dissolving, and, it may be, partly undissolved.

(2) Fatty matter, broken down, but not dissolved.

(3) Starch, being slowly converted into sugar, and as fast as it becomes sugar, dissolving in the fluids of the mixture.

(4) Gastric juice, mixed with substances 1, 2, 3, and liquids, and such portions of aliment as are undigestible.

4. *The Pancreatic Juice* is a clear, colorless liquid, distinguished (1) by its great capacity for digesting fats after they have become fluid by the warmth of the stomach; (2) by its dissolving albuminous substances. It is secreted from a gland, P, about seven inches long, having the form of a bunch of grapes, and generally resembling the salivary glands of the mouth. This juice also enters the duodenum. The salivary glands and the pancreas are readily influenced by the nervous system;

thus, the sight, or smell, or the mere thought of food may prompt the salivary glands to pour saliva into the mouth, or, in common language, cause "the mouth to water."

5. *The Intestinal Juice*, a thin fluid, is secreted from minute glands on the interior surface of the small intestine; its business seems to be to digest albuminous matter which has escaped the action of the gastric juice. The main office of the small intestine is to digest fat. Intestinal juice is also secreted from the colon.

The quantity of these five liquids generated daily has been estimated at 22 pounds, nearly, of which that of the gastric juice amounts to about 14 pounds. It is plain that their office is to dissolve the food and act chemically upon it. Each of them seems to have its special function, and yet none is exclusively directed to one object. They all aid each other, and are in turn assisted by the peristaltic motion of the intestines, which thoroughly mixes the food with them, and propels the chyle from above downward through that portion of the alimentary tube which succeeds the stomach. The undigested masses collect in the rectum to be properly removed.

Read *Constip. of Bowels.* By S. B. Birch. Lindsay & Blakiston, Phila.

LESSON XXVIII.

ASSIMILATION.

Chyme and chyle are merely digested food. Both are in the alimentary tube; one is in the stomach, the other in the intestines. As yet they are strangers to the system—that is to say, they do not form part of it.

The oxygen of the air which enters the lungs rapidly burns up the particles of waste tissue which are thrown into the lungs by the venous blood. Now, this waste matter must be replaced by fresh particles, else the vital processes speedily cease. In other words, at every instant of life a quantity of animal tissue is dying, and must at the next instant be replaced. If no freshly-digested food is at hand, as during disease, the burnt up particles of the body are replaced, first, by the fat of the tissues, and hence the sunken appearance of the eyes and cheeks; or next, by the flesh of the tissues themselves, which results in emaciation, and finally in death, unless cure can be effected. Thus, death and life are intimately associated and dependent upon each other in the living organism.

The question now arises: How is the digested aliment converted into blood so as to be distributed in this form over the entire body, and to replace waste matter—in fact, to furnish the material for the

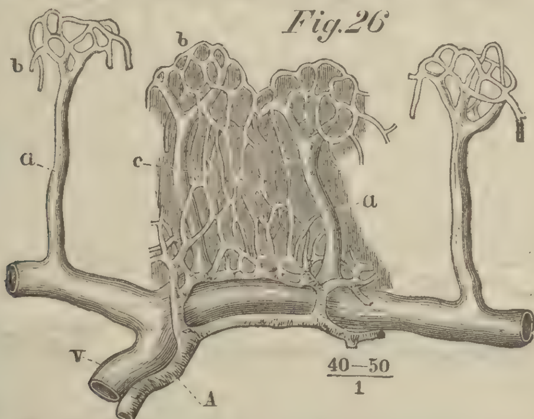
growth and maintenance of the body? The answer is: The chyle throughout the course of the alimentary canal is taken up by capillaries and special minute vessels, called chyle-vessels or lacteals, and conveyed into the circulation at large. With the aid of respiration, it is then made into nourishing blood. The process of taking up the chyle forms part of the process of absorption.

Absorption.—The object of this process is, (1) to supply the blood with fresh materials; (2) to remove such particles as have accomplished their mission in the body. Absorption, then, has a twofold character; it absorbs essentials from *without* the body and carries them to the blood; it absorbs waste materials from *within* the system and conveys them outside the body. Absorption is mainly carried on by two distinct sets of vessels, viz., *blood vessels* or capillaries, and *lacteals* or lymphatics, also called absorbents. The former are abundantly spread over the interior surface of the stomach, and both the small and large intestines; the latter only in the intestinal canal, but most numerously in the small intestine. Both sets of vessels form a perfect network, completely covering the interior surface of the intestinal canal; in the small intestine this network is closer to the chyle than anywhere else.

Absorption by Blood Vessels.—The minute blood-vessels and capillaries in the mucous coat of the stomach and intestines (Fig. 26) absorb at *b* and *c* completely digested aliment; this substance is so finely divided as to readily pass through the walls of the blood-vessels in the manner, roughly speak-

ing, of water passing through (from *without* to the interior of) the walls of a hollow tube made of blotting-paper. The blood at *A* is arterial; on its passage through the capillaries, *b* and *c*, it absorbs chyle (together with waste materials), which renders it venous; through *a* it descends into vein V, to be ultimately conveyed to the lungs. The blood-vessels are not very particular in the choice of fluid particles; they absorb nearly all kinds except the fatty portions. Water, and similar beverages, are believed to be absorbed by the blood-vessels of the stomach without passing into the duodenum.

Fig. 26

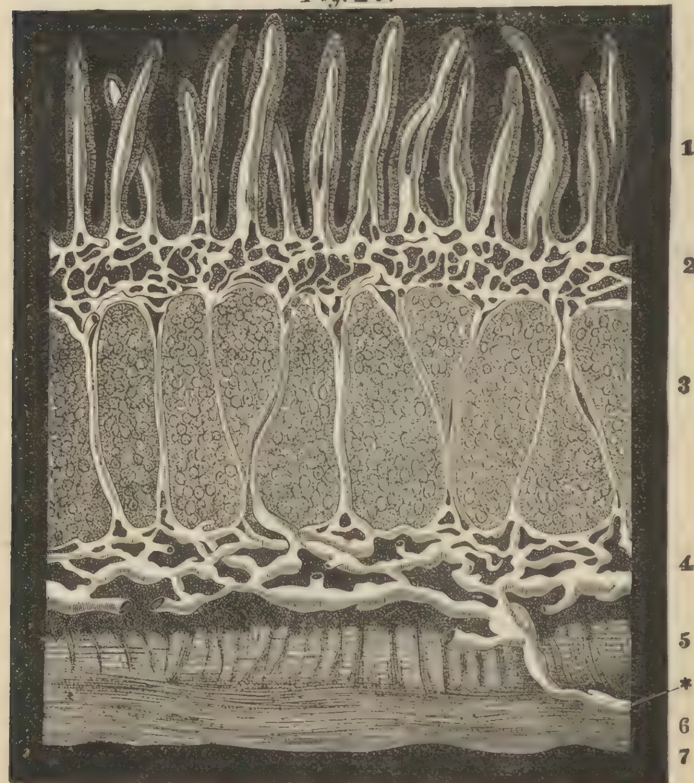


Transverse Section of Mucous Membrane of Colon.
A Artery. *V* Vein. *a a* Descending Veins. *b b* Venous Net on Inner Surface. *c* Capillaries in Mucous Membrane.

Absorption by the Lacteals is carried on in the same manner. It is rendered most effective in the small intestine, because the interior wall of this intestine presents a larger surface to the chyle as it passes

by. This greater extent of surface is owing to the fact that the mucous membrane which forms the interior surface, is folded into a great abundance of

Fig. 27.



Transverse Section of the Duodenum of a Calf.

1 Villi. 2 Interior Chyle-Vessels. 3 Glands. 4 Exterior Chyle-Vessels or Lacteals. 5 6 Muscular Coat. * Valvular Chyle-Duct. 7 Skin.

conical projections, called *villi* (Fig. 27, 1), somewhat resembling the velvety projections of a Turk-

ish towel. From the villi the absorbed materials pass through the interior chyle vessels, 2, and through glands, 3, to the exterior chyle-vessels or lacteals, 4. These vessels gradually increase in size, and on leaving the intestine obtain the valvular structure of veins. This prevents any absorbed chyle from flowing back to the villi. The way in which each *villus* imbibes the chyle is explained thus: the villi have minute muscles which cause them alternately to contract and expand; at every expansion each villus fills with chyle; at every contraction it squeezes its contents into the lymphatic vessels beyond. The villi may be compared to the delicate root-fibres of plants, which are spread in the ground for the purpose of absorbing food for the plant; like the villi, these vegetable fibers are without openings, and yet, as is known from the fact that drooping leaves revive again after a shower on a hot day, they are capable of absorption. The special function of the villi seems to be the absorption of the fatty portion of the chyle, although they absorb also other materials. The villi are found only in the small intestine.

The lymphatic glands receive the chyle from the lymphatic or chyle-vessels (Fig. 27, *) mentioned above. The largest of these glands is the spleen (Fig. 25), situated on the left side of the abdomen. The lymphatic glands are widely distributed in the body. The chyle on passing through them undergoes some change, and on leaving them it flows into the thoracic duct.

The thoracic duct (Fig. 28) is a tube of the width

of a goose quill, nearly, which receives the chyle of the lymphatic vessels and glands, and empties it into a vein on the left side of the chest, near the heart. A similar, smaller tube, likewise throws its contents into a vein on the right side of the chest, near the heart. Thus, the lymphatic vessels are the carriers of the chyle on its way to the blood; they act like veins in this, that they contain valves to make their contents flow in one direction only; with one end they terminate in two ducts, which open into the large veins and finally into the heart; at the other end they terminate in microscopic branches or lymph-capillaries, which are distributed throughout the tissues of the body. The villi form part of these lymph-capillaries. The lymphatic vessels of the intestinal canal pass by the name of *lacteals*, because their contents resemble milk in appearance; there is no difference between lacteals and lymphatics. It should be borne

Fig.28

The Thoracic Duct.

in mind that there are blood-vessels and capillaries within each villus as well as around the villi, which, as before mentioned, carry on absorption.

From the preceding it is evident that man and the higher vertebrates have, in addition to the intricate system of arteries and veins, another system of vessels, called the *lymphatic system*. This contains a fluid called *lymph*, which is chyle altered by the lymphatic glands. As the blood-vessels have blood capillaries, so the lymphatic-vessels have lymph-capillaries near the skin; these widen into lymph-vessels toward the interior of the body.

Read Science Lectures. First Series. Heywood: Manchester.

LESSON XXIX.—REVIEW.

Lesson xxiv.

1. The human body is composed largely of combinations of carbon, nitrogen, hydrogen and oxygen; hence our food must contain these elements.

2. Waste of tissues is due to the incessant work performed by the body; most of this work consists, during life, of (1) the mechanical labor in lifting and moving the body; (2) the maintenance of the standard of temperature; (3) secretion of moisture and carbonic acid.

3. Food may be called any substance adapted to supply the body with material that renews lost tissue or supports some process of life.

4. Food consists of organic and inorganic materials.

5. Organic food comprises (1) nitrogenous substances; (2) fats; (3) compounds of carbon and hydrogen, such as sugar or starch.

6. Inorganic food comprises water, and alkalies, such as salt and phosphates.

7. Substances of too great consistency, or such as are tasteless, are indigestible.

8. The purposes of cooking food are too soften it and to give it an agreeable flavor.

LESSON XXV.—

9. The changes wrought upon the food in the body are (1) digestion, or the proper preparation of food in the alimentary canal; (2) assimilation, or the conversion of food into blood and tissues; (3) excretion, or the decomposition of food.

10. Digestion comprises (1) mastication, (2) insalivation, (3) deglutition, (4) stomach-digestion, (5) digestion in the intestines.

11. The chief functions of the stomach are (1) to mix the food into a pulp; (2) to dissolve the nitrogenous portion of the food by means of the gastric juice.

12. The chief conditions favorable to stomach-digestion are (1) a temperature of 100° F., nearly; (2) continual motion of the walls of the stomach; (3) the removal of thoroughly digested portions of food from the stomach; (4) previous perfect mastication and insalivation of the food; (5) a moderate quantity of food; (6) regular intervals between meals; (7) no severe physical or mental exertion immediately before or after a meal; (8) a tranquil mind; (9) bodily health; (10) favorable weather.

13. The processes undergone by the food between its first introduction into the mouth and its removal from the stomach through the pylorus are (1) mastication, (2) insalivation, (3) deglutition, (4) digestion in the stomach.

LESSON XXVI.—

14. The part of the alimentary canal succeeding the stomach is the intestines. They are divided into the small and the large intestine.

15. The small intestine comprises the duodenum, and the small intestine proper.

16. The large intestine comprises the cæcum, colon, and rectum.

17. The small intestine has peristaltic motion.

18. The digestive fluids are (1) the saliva, (2) the gastric juice, (3) the bile, (4) the pancreatic juice, (5) the intestinal juice.

19. Functions of the saliva:

(1) Softening the food;
(2) Converting starch into sugar;
(3) Mingling the food with air.

Function of the gastric juice: Dissolving albuminous and other substances.

Functions of the bile:

(1) Absorbing waste material from the blood;
(2) Dissolving fatty portions of the food;
(3) Stimulating the action of the intestines.

Functions of the pancreatic juice:

(1) Digesting fats;
(2) Dissolving albuminous substances.

Function of the intestinal juice (probably): Digesting albuminous matter.

20. The food undergoes its most important change in the stomach. When leaving the stomach it is called chyme.

21. Chyme is composed of (1) albuminous matter, (2) fatty matter, (3) starch, (4) gastric juice.

22. After its union with bile, chyme is usually called chyle.

23. The object of absorption is (1) to supply the blood with fresh materials; (2) to remove waste particles.

24. Absorption is effected by blood-vessels (capillaries), and by lacteals (or lymphatics).

25. Absorption by blood-vessels takes place chiefly in the stomach and the intestinal canal. The so absorbed materials are conveyed to veins.

26. Absorption by lacteals takes place in the small intestine by minute vessels called villi; these lead the absorbed chyle into the lacteals or lymphatic vessels, whence it is conveyed through the lymphatic glands to the thoracic duct, and thence thrown into veins.

27. The lymphatic system of the body has its ramifications throughout the body similar to the system of blood-vessels, from which it differs in this, that its fluid is lymph, and flows in only one direction.

28. By the aid of respiration, the chyle is finally made into blood.

29. The want either of proper food or of proper digestion destroys one of the three most essential requirements for health, viz., the proper composition of the blood.

LESSON XXX.

THE NERVOUS SYSTEM — I. THE DIFFERENT PARTS.

General Remarks.—We have become acquainted with the various bones and tissues which compose the *structure* of the body; with some of the muscles which *move* the body; with the *alimentary canal* and its *secretions*, which convert food into nutriment; with the *organs of circulation*—the heart, the blood-vessels, the lymphatics—distributing nutriment all over the body; and with several *organs* serving to withdraw waste material from the body, such as the skin and the lungs. We must now gain an insight into a powerful organ, called the *nervous system.* It is distinct from all other systems in the body. The following are its functions:

1. It connects the different portions and organs of the body into an organic unit or whole. Thus a violent shock to the nervous system, such as great anger or fear, may cause increased action of the heart, an accelerated pulse and immediate loss of consciousness. Here, then, the nervous system acts upon the blood-vessels; these act upon the muscles, and this combined action causes not only single portions of the body to succumb, but the entire body as a unit.

2. It animates, or governs, all movements of the muscles, whether these be voluntary or not. Thus, when a person endeavors to resist a yawn, to repress laughter or tears, a distinct exertion of muscles is requisite for his effort. This is voluntary motion prompted by an act of his will; whereas, the churning motion of the stomach is an example of an involuntary movement governed by the proper nerves.

3. It regulates the temperature, nutrition and secretion of the body. Thus, sudden fear often produces a chilling effect in lowering the temperature of the skin; weakness of the nervous system nearly always impairs the digestive process; intense anguish frequently causes increased perspiration.

4. It controls the processes of nutrition. This may be proved by the fact that the injury of a nerve leading to a tissue is frequently followed by the waste or destruction of the tissue.

5. It receives impressions, which are communicated by its terminal branches. Lateral pressure against the eye-ball causes a luminous impression or image; this is owing to the pressure exerted upon the delicate terminal branches of the optic nerve (Lesson XXXIV).

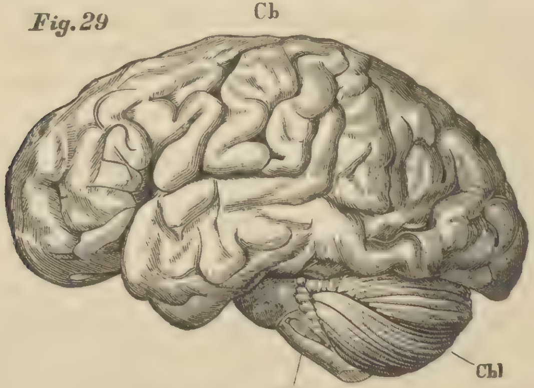
6. It conveys impressions to different portions of the body. In leaping, if a person alights upon the heel he will feel shocking pains in the back part of the head; the impression made at the foot is, by the nerves, conveyed to the head.

7. It can generate influences which no other organ or system can produce, such as sight, smell, taste etc., etc. By virtue of this function, it puts the body in direct communication with the outer world. This is evident, for a living being without the senses of sight, smell, taste, hearing, touch and sensibility, if existing at all, would be utterly unconscious of the world around him.

The performance of all these functions is comprised under the term *Innervation.*

The nervous system, although a continuous substance, is conveniently subdivided into two sys-

Fig. 29



The Brain — (side view).

Cb Cerebrum. Cbl Cerebellum. Mo Medulla Oblongata.

tems: 1, the *cerebro-spinal system*, and 2, the *sympathetic system.* The former comprises the *cerebro-spinal axis*—that is, the *brain* and the *spinal cord*—together with the *cerebral* and *spinal* nerves which emanate from this axis. The sympathetic system

contains the chain of *sympathetic ganglia* and the nerves which they give off.

The Brain (Fig. 29) is a very soft substance, forming in man the enlarged upper terminus of the spinal cord. It is encased in the cavity of the cranium, which it fills, and from which it is difficult to be extracted entire. The brain substance of man generally varies in weight from 40 to 60 ounces, and it is universally admitted that, as a rule, the quantity of brain substance corresponds to the intellectual powers of the individual, although it is be-

Fig.30

$\frac{400}{1}$

Two Nerve Cells and Nerve Fibers. From the Brain. Magnified 400 times.

lieved that the quality of this substance also plays an important part. The brain consists of cells and fibers (Fig. 30), which are rendered visible only by a good microscope. The brain is divided into the large brain or *cerebrum*, the small brain or *cerebellum*—only one-eighth as large as the former—and the enlarged spinal cord or *medulla oblongata*. The cerebrum in man and apes entirely covers the cere-

Fig. 31.

The Spinal Cord, front view, with the projecting nerves cut off.

bellum. The cerebrum and cerebellum consist each of two hemispheres, one on the right, the other on the left side. The surface of the cerebrum is covered with a great many foldings and windings or convolutions, irregular in form and direction; these are separated from each other by deep furrows. The cerebellum also has convolutions, but they are of a more regular form and direction.

The *spinal cord* (Fig. 31) is the downward continuation of the medulla oblongata. It is a soft substance contained in a bony cavity, formed by the vertebral column or back-bone (Lesson II). It extends nearly to the sacrum; it is furrowed like the brain into two lateral, symmetric parts. Between these two parts—that is, in the centre of the cord and through its entire length—runs a fine canal, which originates in a point between the cerebellum and the medulla oblongata.

The *cerebro-spinal nerves* originate in both the brain and the spinal cord, whence they ramify and spread all over the body (Fig. 32). They have the form of fibers and cells. **A nervous fiber is often made up of** minute tubes; each tube contains a

peculiar transparent, semi-solid substance which contains a thick fluid. The nervous fibers terminate in the organs to which they lead, and there form terminal branches. The nervous tubes vary in size from one-thousandth of an inch to much smaller sizes; in the spinal cord they are much smaller; in the brain they are smallest.

Fig. 32.

The Nervous System.

The *sympathetic system* consists, like the brain, of cells and fibers. It is situated in front and at the sides of the spinal column; its ganglia or nerve-cells are connected with one another, and with the spinal nerves by nerve-cords. The *nerves* given off from these ganglia chiefly follow the course of the

blood-vessels, and are copiously distributed over the heart and about the stomach.

The nervous system appears to be composed of two distinct substances—the gray and the white. In the cerebrum and cerebellum the white substance is contained within the gray; in the medulla oblongata and spinal cord, the gray substance is enclosed in the white. The nervous fibers and tubes are white; the cells are gray.

The central organ of the nervous system is the gray substance. This has been admitted by even those who used to think that the intellectual powers had no connection whatever with the nervous system. Scientists agree that the gray substance *evolves* nervous power, while the white mainly serves to *conduct* nervous power. If the white material of the nervous system be compared to a network of telegraph wires spread over a large extent of territory engaged in war, then the gray substance may be likened to the controlling power at headquarters—that is, the commander-in-chief. From all parts telegrams will be sent and transmitted to him along the wires stating the condition of affairs, while he not only sends and transmits messages, but makes his own combinations and plans, and forwards his orders to distant points along the wires.

LESSON XXXI.

THE NERVOUS SYSTEM—II. FUNCTIONS OF THE DIFFERENT PARTS.

The Functions of the Brain.—The thin layer of gray matter upon the hemispheres of the larger and smaller brain is intimately associated with mental operations. The reason for the convolutions and fissures on the surface of the brain is evident: they cause the layer of gray matter to be more extensive, and, consequently, other things being equal, to increase in quantity with the increase of convolutions and fissures. There are strong reasons why the main function of the cerebral hemispheres, and more especially that of the gray matter, seems to be the manifestation of intellectual powers and of powers of the will, viz.:

1. In the animal kingdom, there is generally a correspondence between the quantity of gray matter, depth of convolutions, and the sagacity of the animal.

2. The gray matter of the brain is much more smooth during the first period of the infant's life, and its increase corresponds with the development of intelligence.

3. In diseases which have been known to commence at the circumference of the brain, and to

pass toward the center, medical observations have found that the faculties of the mind are affected *first;* while in those diseases which commence in the central parts of the brain, and thence pass towards the cicumference, they are affected *last.*

4. Experiments upon animals show that when the brain is gradually sliced away, the animal grows more dull and stupid as the quantity of brain cut away increases.

Mental derangement may be caused by (1) imperfect nutrition of the brain; (2) insufficient, or excessive flow of blood toward the brain; (3) a perverse condition of the blood; (4) prolonged sleeplessness; (5) deep affliction or despondency. The usual symptoms of progressing derangement are weakened attention and loss of memory, which should be promptly met by avoidance of physical or nervous excitement, and by proper attention to the body. *Insanity*, a more continuous state of mental derangement, often springs from like sources, but sometimes from hereditary predisposition. Insanity is characterized by lack of appreciation of the proper relations between the self and the external world.

As persons can live though one of their lungs may be seriously injured, so life is not necessarily cut off in case one of the cerebral hemispheres has been damaged.

The functions of the cerebellum, although not distinctly known as yet, seem to be the regulation of muscular movement.

The function of the medulla oblongata consists in generating and controlling the motions of respiration and deglutition. The brain, cerebellum and the spinal cord can be sliced away one after the other without immediately destroying life; whereas, an interference with the medulla oblongata is followed by instantaneous death.

Functions of the spinal cord.—1. To transmit sensitive impressions from its outer nerves to the brain. 2. To transmit the manifestations of the will from the brain to the spinal-motor nerves, which result in muscular activity. 3. To originate nerve-force independently of the brain whenever a stimulus is applied. Thus, when a stimulus, such as a drop of acid, is applied to the upper leg of a decapitated frog, he brings the toes of the corresponding foot to the place to wipe off the acid, but he will not leap away. In this case an impression has been made upon a sensitive nerve leading to the spinal cord. This sensitive or *sensory* nerve conveyed the impression to the spinal cord, the spinal cord made response to the impression through a *motor* nerve, and this response resulted in the *reflex* action of the foot. So when, independent of any influence of the brain, a small piece of bread is passed into the gullet by voluntary motion, it will be urged onward to the stomach by involuntary motion—that is, by the reflex action of the spinal cord. The bread here acts as an exciting stimulus upon the spinal marrow, which generates motor power; this motor power is 'reflected' back and produces the involuntary movements or

reflex action of the muscles whose sensitive fibers were stimulated.

The functions of the sympathetic system are not fully known as yet. It would appear, however, that while it is intimately connected with the other divisions of the nervous system, it presides over the actions of the alimentary canal, the glands, the blood-vessels and the heart. The heart may be removed from the body, and yet its rhythmical movements will continue for a number of minutes. This independent motor power on the part of the heart can only be explained by the existence of sympathetic ganglia or centers linked together by delicate nerve filaments, constituting of themselves a distinct nervous system.

Functions of Nerves.—If the nerve of a tooth be divided, the tooth has lost its sensibility. If the nerves leading to the biceps be severed, this muscle loses its motor power; it will no longer move the forearm. If these nerves be exposed in their course and irritated, the biceps will be thrown into violent movements, and intense pains experienced as coming from the biceps. These facts show that the nerves, generally speaking, are endowed with *motor* and *sensory* properties. That is to say, the nerves enable us to seize ordinary sensations, and to perform acts of motion.

There are nerves which are specially engaged in motion, and others, such as the optic nerve, which generate merely sensations. Either class may be injured without any damage to the other. Thus, a blind man rolling his eyes shows that, though his

optic nerve is blighted, the motor nerves are in full action. So a limb may be *paralyzed*—that is, deprived of all motion—and yet be very sensitive. If a motor nerve be divided, and a galvanic current applied to the portion of the nerve connected with the muscle, the muscle contracts. This shows that motor nerves act like telegraphic wires.

Cases have been known where soldiers complained of pain in their limb, which had long before been amputated. This is evidence that sensory nerves act like insulated wires, and, besides, that we refer pain and all other sensations to the parts which are supplied with nerves; we suppose the sensation to exist in the direction from which the nerves communicate it.

The nerves leading from the brain to the eye, ear, etc., etc., are in pairs; also those originating in the spinal cord. The latter are distributed nearly over the whole body, and are endowed with both motor and sensory properties.

Read *Dynamics of Nerve and Muscle.* C. B. Radcliffe. Macmillan & Co.

LESSON XXXII.—REVIEW.

LESSON XXX.—

1. Functions of the nervous system :
   (1) It connects the different parts and organs of the body into an organic unit or whole.
   (2) It animates or governs all movements of the muscles, whether voluntary or not.
   (3) It regulates the temperature, nutrition and secretion of the body.
   (4) It controls the processes of the organic life of the body.
   (5) It receives impressions which are generated by its terminal branches.
   (6) It conveys impresssions to different portions of the body.
   (7) It can generate influences which no other organ or system can produce, such as sight, smell or taste. By means of this function, it puts the body in direct communication with the outer world.

2. The nervous system is subdivided into the cerebro-spinal system and the sympathetic.

3. The brain is divided into the cerebrum, the cerebellum and the medulla oblongata.

4. The nervous system appears to be composed of two distinct substances, the gray and the white.

5. The gray substance is the central organ of the nervous system.

LESSON XXXI.—

6. The main function of the cerebrum seems to be the manifestation of intellectual powers, and of the will.

7. The functions of the cerebellum seem to consist in the regulation of muscular movements.

8. The function of the medulla oblongata is to generate and control the motions of respiration and deglutition.

9. The functions of the spinal cord are—(1) to transmit sensitive impressions from its outer nerves to the brain; (2) to transmit the manifestations of the will from the brain to the spinal-motor nerves; (3) to originate nerve-force independently of the brain whenever a stimulus is applied.

10. The functions of the sympathetic system seem to be, to control the action of the alimentary canal, the glands, the blood-vessels and the heart.

11. Nerves are generally endowed with motor and sensory properties. There are some which have only motor properties, and others which serve the purpose of generating sensations.

LESSON XXXIII.

THE SENSES IN GENERAL.—THE SENSE OF TOUCH.

The ideas, words and actions of a human being are largely dependent upon the soundness and the training of his sensory organs.

Sensory organs are tools, or instruments, capable (1) of receiving impressions from the outer world, and (2) of making us conscious of those impressions. The means by which consciousness of impressions arises is *sensation*. Thus, the eye with its proper nerves is a sensory organ; it is capable of receiving the impression that a certain ribbon is blue; there is no other organ which can obtain such an impression. The eye, besides being capable of receiving that impression, is also capable of making us conscious of it, viz., the blue color. A man, after his eyes were removed, would be utterly incaple of recognizing the blue tint, although his mind were never so clear.

Sensation, in the present example, is excited by the action of the blue rays upon the retina; so we speak of the sensation of cold, meaning by it the peculiar effect which cold has upon the nerves.

Nearly all sensations come from without the body—that is, from the outer world; they may be

called objective sensations. The yellow color of a lemon, the blue color of a ribbon, are objective sensations. It sometimes happens that the nerves of a sensory organ are affected when there is no objective or outside cause whatever. In this case they make us believe things that have actually no existence. The eye, for example, if closed and pressed upon with a finger, develops a luminous image; this sensation is drawn not from the exterior world, but solely from within the body, hence, is not objective, but *subjective.* The peculiar noise known as the 'humming of the ear' is also a subjective sensation.

The sensory organs are five in number, viz., that of sight, hearing, touch, taste and smell. They are merely the peculiarly shaped termination of a particular nerve. Impressions acting upon this termination, or anywhere upon the nerve, whether coming from within the body or from without, affect it in a way that is peculiar to it, and concerning which nothing positive is known. Thus, the eye-ball is so constructed as to collect a great number of rays of light which affect the optic nerve, and thereby produce the sensation of sight. What becomes of this sensation—that is, in what manner it produces the consciousness of sight, and in what manner it ultimately serves intellectual functions, we do not know, and probably never shall. The ear is utterly blind to the minute waves of light but very sensitive to the ærial waves of sound. So each organ has a distinct structure, in virtue of which it has its

particular manifestations; and the different senses may be compared to the various departments of government in a country, all of which together make up the government itself.

THE SENSE OF TOUCH.

Pressure, *resistance*, smoothness, roughness, hardness, softness, also *cold* and *heat*, are the most common sensations excited by the sense of touch. The distinct structure of this sense consists in the nerves, which are spread out under the epidermis (Lesson XIII.) and within the dermis or cutis. It is a curious fact that the proper sensation is excited only on condition that the epidermis (which is known to contain no nerves) lie between the expanded nerves in the dermis and the exciting agent; that is to say, the stimulus or exciting agent must not be in direct contact with the dermis. If by accident, as by burning, the epidermis has been destroyed, the sense of touch of the exposed nerve is reduced to a mere sense of pain. The termination of these nerves is not a flat surface, but consists of a great number of small, conical projections, called *papillæ*. Different portions of the body possess different degrees of sensibility; compare the acuteness of the finger tips with the dullness of the neck. The amount of sensibility is greatly lessened when the skin is stretched.

A person who takes hold of an exceedingly cold iron bar experiences a sensation nearly like that obtained by touching one overheated. The toothache caused by the contact of a tooth with ice

cream is the same as that resulting from severe heat applied to the tooth. These well-known facts show that an excess of cold or heat causes pain instead of impression of temperature; the pain is the same, by whichever it may be caused.

Beyond the dermis the nerves are insensible to heat and cold; so the optic nerve, beyond its expansion—the retina—is no longer sensitive to light.

The sense of touch is capable of great improvement. 'Professor Saunders, of Cambridge, who lost his sight when two years old, could distinguish by this sense genuine medals from imitation ones. Other blind men have, by their exquisite touch, been enabled to become sculptors, conchologists, botanists,' etc., etc.

LESSON XXXIV.

THE SENSES OF TASTE AND SMELL.

TASTE.—*Sweetness*, *acidity* and *pungency* are sensations most frequently excited by this sense. Its distinct structure consists of *papillæ* spread over the tongue and portions of the cavity of the mouth. These papillæ are the terminations of certain nerves coming from the brain.

The sense of taste varies greatly in different persons; it depends upon education, habits, and often upon imagination. It is diminished when the mucous surfaces of the tongue and mouth are affected, as in case of fever. It is a remarkable fact that when one part of the tongue is injured or paralyzed, the other has its capacity for tasting unimpaired.

The sensations of taste are largely connected with those of other senses, such as smell, touch, and even sight. Thus, when the nose is held tightly closed so as to obtain no smell, the taste of many a substance is rendered difficult to distinguish; and it is very nearly the same if the sense of sight is interfered with.

SMELL.—*Fragrance* and *fetor* are the principal sensations excited by this sense. Its distinct structure consists in olfactory nerves, which are spread

over the interior surface of the nasal cavity, and protected by the latter. The olfactory nerves commence higher up in the nose; the lower portion of the nose warms the cold air as it ascends, and thus protects the sensitive surface higher up. It also prevents the latter from becoming dry; this is of the greatest importance, as the function of the olfactory nerve ceases when the nasal chambers are dry. Substances, in order to produce smell, must have the gaseous form. This does not mean that all gases are odoriferous; for oxygen, nitrogen, hydrogen, and many other gases, when in the pure state, are odorless. The fragrance of a rose, for example, is caused by particles of the flower being diffused in the air and transmitted to the olfactory nerve by means of a current of air inhaled during the act of inspiration. Like taste, smell may be sharpened by education and habit.

As a rule, we judge localities with strong odors to be unhealthy. The escape of illuminating gas is easily detected by its odor, and may be fatal to the inmates of a room. Many strong odors, however, are harmless, while, on the other hand, quite inodorous atmospheric air may contain the germs of the most dangerous epidemics. Such is the case with the air of low grounds, marshes and swamps. The connection between bad odors and pernicious effects is not yet cleared up; the production of odor is closely connected with that of chemical action.

LESSON XXXV.

SIGHT.—I.

Light, colors of all kinds, and vision generally, are the principal sensations derived from the organ of sight. Its structure comprises the eye-ball and its accessory organs. The eye-ball owes its bulb-like form, solid appearance and resistance to pressure from without and within to a hard, fibrous membrane, covering it entirely, and having in front a transparent, horny part.

The eye-ball consists of (1) three distinct coats, and (2) an optical apparatus.

I. *The three coats* of the eye (Fig. 33):

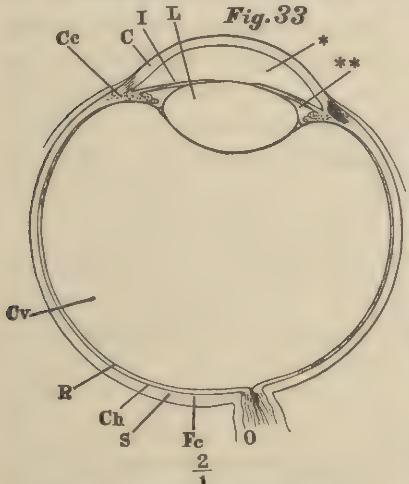
a. The Sclerotic.—This membrane is the outer coat of the eye; four-fifths of it is white, opaque, hard, very little elastic; it forms the rear portions of the membrane, the remaining one-fifth being the front part, a sort of window, called the *cornea.* The sclerotic gives form to the eye, serves for the attachment of muscles and envelops and protects the parts within. Both sclerotic and cornea are hard, but the cornea is colorless, transparent, and elastic.

b. The Choroid.—It lines all the interior of the sclerotic with the exception of the optic nerve entrance. It contains a capillary network of blood-vessels to feed and warm the eye. It is soft and

elastic, and lined within by a black tissue, or pigment, to absorb unnecessary rays of light. Where this pigment is wanting, as in albinos, a confusion of sight is caused in daylight, probably because the unnecessary rays of light are reflected instead of absorbed.

The Iris.—The bulb of the eye is divided into two unequal parts by a muscular membrane, the *iris*, forming a sort of curtain, with a central opening, the *pupil*, to admit the rays of light. The iris is lined on its rear surface by the choroid; in front it is provided with coloring matter, which determines the color of the eye. The iris possesses only involuntary muscular fibers (*ciliary processes*), by the aid of which it contracts—and thus enlarges the pupil—when a greater amount of light is needed; and it dilates—thus diminishing the aperture—when light is abundant. Thus, the iris regu-

Fig. 33



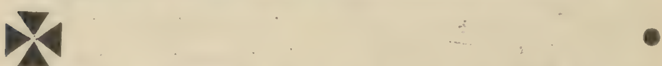
The Eye-Ball — Horizontal Section.

S Sclerotic Coat. *C* Cornea.
Ch Choroid Coat. *I* Iris.
Cc Ciliary Processes. *R* Retina.
O Optic Nerve (blind spot).
* Aqueous Humor (anterior chamber).
** Aqueous Humor (posterior chamber).
L Crystalline Lens.
Cv Vitreous Humor.
Fc Yellow Spot (optic axis).

lates the supply of light required for distinct vision.

c. *Retina.*—Both sclerotic and choroid coats are pierced so as to admit the optic nerve. This nerve comes from the brain and enters the eye-ball from the rear. On reaching the interior surface of the choroid coat, the optic nerve divides into minute branches, which are so densely interwoven among each other that they form a nerve membrane, very delicate in structure, and about $\frac{1}{40}$ of an inch in thickness. The point where it enters the choroid is not in the main axis of the eye-ball—a straight line drawn through the center of the pupil and bisecting the eye-ball—but is situated toward the inner corner of the eye. This point is not sensitive to light, and, therefore, called the 'blind' spot. It is ascertained by the following simple experiment:

14. Experiment.—Close the left eye; with the right eye look steadily at the cross below, holding the page at a distance of about twelve inches.



In this position both dot and cross will be seen distinctly. But if the book be slowly brought nearer to the face, the right eye being still fixed upon the cross, the dot will disappear during an instant, and as the book approaches the face, becomes visible again. Now, during the instant that the dot vanished out of sight, the image of the dot was on the *blind spot* of the retina—that is, on the region of the retina where the optic nerve enters the choroid.

II. *The Optical Apparatus.*—This is transparent, and refracts the light-rays to the retina. It consists of four lenses: *a*, the *cornea*, the network of the lenses ; *b*, the *aqueous humor*, the second lens from the front, a watery liquid containing a little salt; *c*, the *crystalline lens*, the third lens, one of the most peculiar bodies in existence, which has the appearance of a double-convex glass, and is situated between the iris and the vitreous humor; *d*, the *vitreous humor*, the fourth lens. It is filled with a watery fluid, and forms by far the largest part of the eye-ball.

Thus, the optical apparatus of the eye comprises two solid substances—a horny and a glassy one—and two liquids, all four serving the purpose of lenses. There is no artificial contrivance which approaches it in excellence.

The eyebrows serve to guard the eye against excess of light; the eyelids, to keep the surface of the cornea moist; the eyelashes, to retain dust floating in the atmosphere. The remarkable mobility of the eye-ball is effected by a number of muscles, which act upon it in various directions.

Read 'Our Eyes.' By H. W. Williams. J. Osgood & Co.: Boston.
Read 'Diseases of the Eye.' James Dixon. Lindsay & Blakiston: Phila.

LESSON XXXVI.

SIGHT.—II.

The accommodation of the eye.—If a small box, blackened on the inside, be provided with a convex lens or a watch-glass, placed in one of its sides—which is then the front side of the box—we have a *camera obscura.* The lens collects rays of light from the objects before it; an image of these objects is produced somewhere in the box. We can catch the image by inserting a piece of ground glass, and it will then be distinctly visible; or, if a sensitive photographic plate be taken in place of the glass, the image will be fixed on the plate. This is the principle of photography. If the image be examined, we shall find that only those spots are pictured on it distinctly which are nearly at the same distance from the lens; the image of objects farther off is brought to a focus in front of the plate; that of objects nearer to the lens, behind the plate.

A little thinking will enable us to see that the eye may be compared to such a camera. The box corresponds to the sclerotic coat; the lens answers to the cornea and crystalline lens; the glass plate, or the back of the box, to the retina. Were we to fill the box with water, this fluid would indicate the fluids of the eye. It will here be observed that in

the camera we have nothing for the iris; so we must imagine an opaque plate with a hole in the center, suspended directly behind the watch-glass, whose purpose it should be to regulate the supply of light. But the camera has yet another defect, viz.: it has no means of adjusting the focus so as to view objects at different distances. In order to obtain the images of objects at a greater distance we might move the glass plate toward the lens; and, on the other hand, to receive the images of objects situated nearer, the plate would have to be pushed farther back. We might also slide the lens forward and backward, as is done in the ordinary camera. Or we might effect the adjustment in still another way: take a very convex lens to obtain the image of nearer objects, and exchange it for a less convex one when the image of distant objects is to be thrown on the plate.

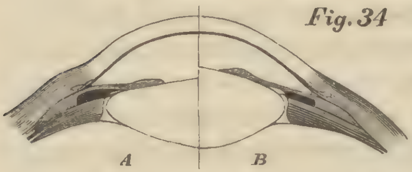
But the simplest way of all would be, if one and the same lens could be made to alter its convexity so as to adjust itself of its own accord to distances. This actually occurs in the eye.

15. Experiment.—Stick two pins upright into a straight piece of wood, not quite, but nearly, in a straight line, with the eye applied to one end of the wood; one pin to be about six inches from the eye, the other about twelve inches. If we look at the nearer pin first we shall see it very distinctly, while the other pin produces a blurred image. If now we look at the other pin the blurred image will at once become distinct, but we feel that somewhere in the eye an effort had first to be made. We observe,

also, that the nearer pin now yields a blurred image, and on repeated trials, it appears evident that we utterly fail to see both pins distinctly at the same instant of time.

This experiment, as well as a great many familiar facts of the kind, proves that the eye can see an object distinctly at different distances. Hence, it must be that the eye has the capacity of adjusting itself according to the distance of objects. This accommodation on the part of the eye is brought about by a change in the form of the crystalline lens. The lens is flattened when a more distant object is viewed (Fig. 34, A), and becomes more convex (B) when the object to be viewed is nearer.

Fig. 34



The distance of distinct vision is about ten inches. This means that, generally speaking, no object which is brought within less than ten inches of the eye can be rendered distinctly visible without effort. There is a certain range within which alone the adjustment of the eye can take place. It is subject to personal variation.

Short-sightedness and long-sightedness arise often from a defect in the adjusting powers of the eye. In some persons the cornea is more convex than usual, or the refractive powers of the eye are greatly increased. Such persons are short-sighted (or near-sighted): they can see only near objects distinctly,

because objects at ordinary distances have their rays come to a focus, not on the retina, but in front of the retina. The images of these objects are thereby rendered indistinct, for the rays, instead of blending into points, form minute circles upon the retina, which causes the blurred appearance of the images. Some people, especially such as are advanced in years, have the cornea flattened—that is, not sufficiently convex—and for this reason the rays from objects at ordinary distances are not brought to a focus on the retina, but behind it. Either defect is amended by suitable glasses. Short-sighted persons require concave glasses—glasses thinnest in the center—which counteract the greater convexity of the eye. Long-sighted people wear convex glasses—glasses thickest in the center—so as to render the eye apparently more convex.

Visible Direction.—From the observation of all images formed by rays of light after crossing each other through an aperture, it is evident that the images or external objects are inverted upon the retina. The probable reason why we do not see all objects inverted is our habit of supposing that the point from which a ray strikes us lies in the direction from whence the ray comes. Thus, a point at the top of a steeple, although on the retina pictured *below*, is by the mind supposed to be situated *above*, because its ray strikes the retina from above. (See First Lessons in Physics, Lesson XXXIV.)

Duration of Impressions upon the Retina.—When the retina has received an impression of light

it retains the impression a little longer than during the actual time in which the light lasts. A luminous impression, however short the time during which the light itself lasts, usually remains on the retina one-eighth of a second. Supposing that two luminous points were to act successively upon the retina in a less interval than one-eighth of a second, then the two impressions would appear as one impression. This explains why a lighted stick, if turned round very rapidly by the hand, appears as a luminous circle; or why a vibrating string may be visible as a sort of broad film.

Color-blindness is probably a defect in the retina, or in the humors of the eye, of persons who are unable to distinguish between certain colors, and sometimes even have no appreciation of any color. They are said to be *color-blind.*

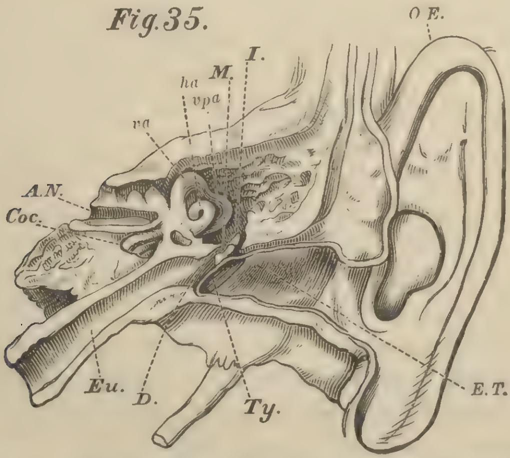
The sensitiveness of the retina is readily diminished. If we look steadily at an intensely bright light, the part of the retina on which the rays fall is rapidly weakened, and even temporarily blinded. This may be ascertained by turning from the bright light toward a moderately lighted surface; the dark spot which then comes to view is the result of momentary blindness in that part. It is also injurious to strain the eye when the supply of light is insufficient, as when persons attempt to read during twilight.

LESSON XXXVII.

HEARING.

Sound, *noise* and *music* are the principal sensations derived from the sense of hearing. The organ of hearing is the ear. The eye has an optical apparatus to convey waves of light to the terminal branch of the optic nerve, the retina; so the ear has a complex apparatus for the transmission of waves of sound to the terminal branches of the auditory nerve.

Fig. 35.



THE EAR.—Transverse Section through the Side Walls of the Skull.

OE	Outer Ear.	*M*	Hammer.
ET	External Tube.	*I*	Anvil.
Ty	Tympanic Membrane.	*va, ha, vpa*	Semicircular Canals.
D	Drum or Tympanum.	*Coc*	Cochlea.
Eu	Eustachian Tube.	*AN*	Auditory Nerve.

The general structure of the ear (Fig. 35) consists of (1) the *outer ear;* (2) the *middle ear;* (3) the *labyrinth*, a complicated system of canals, which is filled with a liquid resembling water.

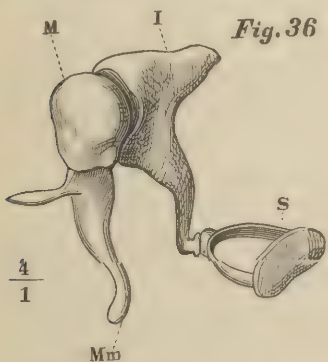
1. *The outer ear* (Fig. 35, OE) is a cartilage, shaped somewhat like a funnel, and provided with muscles. On account of its shape and elasticity it is peculiarly adapted to collect and transmit waves of sound.

2. *The middle ear* consists of (1) the *external tube*, E T, and (2) the *drum*, or *tympanum*, D (scarcely visible in Fig. 35). The former may be considered the tube of the funnel, formed by the outer ear. The outer wall is cartilaginous; its inner, of bony tissue. Its rear end is closed by the *tympanic membrane*, Ty, a translucent, delicate membrane which is stretched across the tube in an oblique direction. Were it not for this membrane the external tube and the drum would form a single passage. The drum is a cavity filled with air, bordered at one end by the tympanic membrane, at the other by two openings—one called the *oval* window (Fv, Fig. 37), the other the *round* window (Fc, Fig. 37). In the fresh state each of these openings is firmly closed by a membrane; in the dry skull both are wide open, and lead into the labyrinth. The drum also communicates with the roof of the mouth by means of a long passage called the *Eustachian tube*, Eu. This canal serves the purpose of equalizing the temperature as well as the pressure of air on

either side of the tympanic membrance, an important item for the healthy state of the ear.

The drum contains three small bones (Fig. 36); the *hammer*, *M*, the handle of which (*Mm*) is fastened to the inner side of the tympanic membrane; the *anvil*, *I;* and the *stapes S.* The head of the hammer forms a joint with the anvil; the foot-plate of the stapes closes the oval window. These small bones make connection between the tympanic membrane and the labyrinth, or more properly, the oval window (Fv, Fig. 37) which leads to the labyrinth. They convey the vibrations of the tympanic membrane to the labyrinth.

Fig. 36



The Small Bones of the Ear.

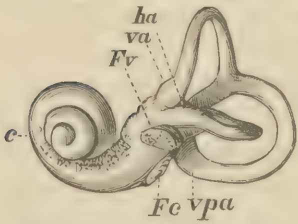
3. *The Inner Ear, or Labyrinth*, consists of (1) the *vestibule* (not visible in Fig. 37), a chamber which is connected with the drum by means of the oval window. (2) Three hoop-like *semi-circular* canals, viz., two vertical ones, *va*, *vpa*, and one horizontal, *ha*. (3) The *cochlea*, *c*, a cavity having the form of a spiral shell, with two and a half windings.

Thus, the entire labyrinth consists of chambers and canals which are hollowed out in the solid portion of the temporal bone (Lesson II.). Each such cavity contains a fluid in which are floating minute branches of the auditory nerve (AN. Fig. 35).

11

The sensation of sound is excited in about this way: The outer ear collects waves of sound, and conveys them through the external tube to the tympanic membrane, which is shaken by these waves, and causes the three small bones to vibrate. The last of these bones, the stapes, impinges upon the vestibule, to which it imparts its vibrations. These are at once taken up by the fluid in the vestibule and transmitted to the remaining liquids in the various canals composing the labyrinth. The motion of the liquids causes the minute fibers and hair like terminations of the auditory nerve, which are floating freely in the liquids, to vibrate; and their vibrations are carried by the auditory nerve to the brain.

Fig. 37



The Labyrtnth—(ext. view).

Read 'Deafness.' E. B. Lighthill. Carleton: New York.
Read 'Sight and Hearing.' J. H. Clarke. Scribner & Armstrong: N. Y.

LESSON XXXVIII.—REVIEW.

LESSON XXXIII.—

1. Sensory organs are capable (1) of receiving impressions from the outer world, and (2) of making us conscious of these impressions.

2. The means by which the consciousness of impressions arises within us is called sensation.

3. The structure of the sense of touch consists in nerves which are spread out under the epidermis.

LESSON XXXIV.

4. The structure of the sense of taste consists in *papillæ* spread over the tongue and portions of the cavity of the mouth. Papillæ are the terminations of certain nerves coming from the brain.

5. The structure of the sense of smell consists in olfactory nerves, which are spread over the interior surface of the nasal cavity.

LESSON XXXV.—

6. The structure of the sense of sight consists in two eye-balls, each of which comprises (1) three distinct coats, and (2) an optical apparatus.

7. The three coats of the eye-ball are:

   (1) The sclerotic coat;
   (2) The choroid coat;
   (3) The retina.

8. The retina is the terminal expansion of the optic nerve. Both optic nerves unite into one optic nerve in the brain.

9. The optical apparatus is made up of—

(1) The cornea;
(2) The aqueous humor;
(3) The crystalline lens;
(4) The vitreous humor.

LESSON XXXVI.—

10. The eye is capable of adjusting itself according to the distances of objects. This power is called the *accommodation* of the eye.

11. The distance of distinct vision of the eye is about ten inches.

12. Short-sightedness and long-sightedness are remedied by concave and convex glasses, respectively.

13. The visible direction of the eye is our habit of supposing the point from which a ray strikes it to lie in the direction from whence the ray comes.

14. The retina retains impressions a little longer than during the actual time in which the light lasts.

15. Color-blindness is a defect of persons in distinguishing between certain colors, or the impossibility of detecting any color.

16. The sensitiveness of the retina is readily exhausted.

LESSON XXXVII.—

17. The structure of the sense of hearing consists of two ears, each of which comprises (1) the outer ear, (2) the middle ear, (3) the inner ear or labyrinth.

18. The outer ear is peculiarly adapted to collect and transmit waves of sound.

19. The middle ear consists of (1) the external tube, and (2) the drum or tympanum. These are separated from each other by the tympanic membrane. The drum contains three small bones: the hammer, the anvil and the stapes. Its inner end contains the oval window and the round window. The three small bones connect the tympanum—that is, the tympanic membrane—with the oval window.

20. The labyrinth or inner ear consists of the vestibule, three semi-circular canals and the cochlea.

21. The labyrinth is filled with liquids, in which are floating the terminal fibers and filaments of the auditory nerve.

LESSON XXXIX.

THE MIND.

We have now seen that man possesses a passive framework composed of bones, which form the levers by which he accomplishes his movements. These levers are acted upon by the muscles, which thereby become the proper organs of motion. These, in turn, are controlled to a greater or less extent by the nervous system. The bones, muscles, sensory organs and nervous system have very properly been called the 'Animal Apparatus of Life'; they are found in all the higher animals.

Now, there is another function apparent in the human body, in virtue of which a constant *building-up* or *repairing* of these essentials of animal life is going on within the body, which is called for by the continuous wear and tear of bones, muscles and blood. This function is performed by organs which (1) make blood, such as the alimentary canal and the lymphatics; (2) keep the blood in circulation, as the heart; and (3) maintain it in a pure state, as the lungs. These organs have been comprised under the head of 'Organic Apparatus of Life,' and are also influenced by the nervous system.

The animal apparatus of life intimately connects

man with the highest animals; the organic apparatus of life with the vegetable kingdom.

Many of the higher species of animals have been greatly changed by domestication. Their ferocious habits have been modified, their instincts improved, their intelligence developed; but in spite of all this, domesticated races, when left to themselves, after a few generations return to their original wildness. And the superiority of training which an individual animal may have received never benefits his species or race.

With the human being it is very different. Man is gifted not only with an unlimited capacity for mental accomplishment, but also with a never-ending desire to acquire new mental attainments. And individuals of ability and talent seldom fail to benefit their race. From these gifts spring the eagerness of the human being for *education*. Education consists chiefly in repressing the lower habits of human nature, and in developing its nobler qualities.

Beyond all this there exists yet something more elevated, though more difficult to analyze, viz.: the faculty which enables us to conceive the idea of the infinite and our relations to the infinite, by which we possess aspirations after *Truth*, *Goodness*, *Right* and *Beauty*.

If the capacity for, *and desire after*, mental accomplishment, referred to above, be expressed by

the term *Mind*, we must recognize (*a*) that the mind is greatly dependent upon the condition and the state of health of the body, and (*b*) that the body, in turn, is easily affected by the mind. There are many familiar facts to testify to this, among which may be mentioned as proofs of *a*: (1) The necessity of proper food to nourish the brain: that is, of pure blood with an abundance of oxygen. Wherever this is wanting, mental activity decreases. (2) The effect of local affections of the brain, as when a person has received a severe blow on the head. (3) The effect of intoxication, or (4) of poison, or (5) of fever, or other bodily disorder. And among the numerous proofs of *b* we have: (1) The well-known effects of anxiety, fear or joy on the body. (2) The injurious effect of mental depression on bodily functions. (3) The self-restraint exerted by the body in obedience to efforts of the will.

Attention.—Every individual has a certain capacity of concentrating his faculties upon a task which he wishes to perform. Thus, he may wish to acquire knowledge, to repress his anger, to control his habits, or to observe strict honesty in his dealings with others; but for any and all of these activities he needs a certain power of will. This power of will he must bring to bear upon his faculties in order to be successful. If all his faculties are directed upon any one activity at a time, as for example, upon the acquisition of mathematics, he nearly excludes them from any other activity, and is then said to be *attentive*. Attention, therefore, is

the concentration by the power of will of all the faculties upon some one activity to the exclusion of others. Thus, a young person who is bent over his slate, concentrating all his activities upon an arithmetical problem, is almost unaware of what is going on around him. His will deprives the sensory organs of nearly all their faculties, which are now spent in *inward* attention. On the other hand, a countryman visiting a large town for the first time, does not follow any particular train of thought, but has his senses busily engaged by the novelties with which he is impressed at every step. His will does not direct his faculties to any special activity; they are devoted to his sensory organs, and, consequently, his attention is wholly *outward*.

Perception.—A sleeping person may unconsciously start at a loud noise, and then resume his former state of sleep. His sensation was correct; he was conscious of it, but he had no distinct *perception* regarding the source or nature of the sound, because he bestowed no attention upon it. Or, if the young student, referred to above, had been less absorbed by his mathematical problem, he might have unconsciously heard cries outside of his room, and yet not have had a distinct perception of them; and having finished his task, and hearing the cries again, this time with his full attention directed toward them, he may dimly remember to have heard them before. While, then, a *sensation* is an impression upon a conscious state of mind, a *perception* is an impression upon a conscious state of mind accompanied by attention; or, perception = sensation +

attention. From the preceding it will be clear that a person having heard a loud report at a distance repeated several times, in speaking about it will, with perfect propriety, describe the *sensation* which the sound produced in *himself*, and which, as yet, he may attribute to the roaring of cannon, or thunder, or to an explosion. Now, let him arrive on the spot from whence the noise proceeded. Suppose it to have been due to the practice of artillery. He will then *perceive* the source and the nature of the report, and thus obtain a distinct *perception* of the cannon, which he may afterwards describe. He has now learned something *outside of himself*, and his mind is no longer engrossed with its own sensation.

Ideas.—After his return, the same person can accurately picture the cannon and represent to himself its effect; that is, he has retained a *mental representation* or *idea* of the object and its effect. This idea he can afterwards reproduce in audible or visible signs—words; or, if he is an artist, he can paint it. *An idea is the mental representation of an object;* it calls for a higher mental activity than perception.

A succession of ideas gives rise to *thought.* The conscious mind is incessantly engaged in thought. We might continue, and treat of the laws of thought, emotion, habit, will, sleep and dreams, but the limits of the present volume have now been attained. For further information, the young student should, throughout the course, peruse the works of reference indicated.

Definition of Physiology.—Physiology is the science of the functions of animals and vegetables. *Human physiology* is the science which treats of the functions of the human body and the manner in which they are brought about.

Read *Mental Hygiene.* D. A. Gorton. Lippincott: Phila.
Expression of the Emotions. Darwin.
Body and Mind. Maudsley. Macmillan & Co.: New York.
Diseases of Brain. By Forbes Winslow. Churchill & Son: Lond.
Disorders of the Mind. By F. Winslow. Churchill & Son: Lond.

LESSON XL.

ALCOHOL — STIMULANTS — NARCOTICS.

ALCOHOL.

1. *Properties.* — If sugar be allowed to ferment, one of the products of this fermentation is alcohol.

Pure alcohol is a highly volatile thin-fluid, combustible liquid, of a vivifying odor and burning taste. It is specifically lighter than water, having a specific gravity of about 0.8, which means that a given volume of it weighs only about $\frac{8}{10}$ as much as the same volume of pure water. Its boiling point is lower than that of water, being about 175° Fahrenheit (that of water being 212 F.°).

It has a strong attraction for water, and mixes with it in all proportions. What is known as the ordinary alcohol of commerce is pure alcohol mixed with water.

A drop of it placed upon the skin produces the sensation of cold, which is due to its rapid evaporation.

2. *Uses.* — Alcohol is used in the arts for many useful purposes. On account of its great capacity of dissolving substances, it is used as a solvent of rosins, cements, pharmaceutical preparations, and for the manufacture of perfumes and essential oils.

On account of its capacity for preserving vegetable and animal fibres, it is used to preserve anatomical preparations and articles of food.

On account of its stimulating powers it is used by physicians in small quantities greatly diluted with water, to promote or stimulate the action of organs such as the heart or stomach. But instead of using pure alcohol diluted with water, pure light wines are usually recommended by physicians on account of their flavor, as all such wines contain a small portion of alcohol.

3. *General Effects.* — Beer, wine, liquors and whatever other names the different beverages may bear that are used by mankind on account of the effects which the smaller or greater percentage of alcohol they contain may exert, are known for their general effects upon the human system as well as for the certain special effects which we will describe hereafter. Most people use them as stimulants, some as medicine, and some — the unfortunate victims of a slavish desire — as a means of reaching an early grave.

What is a "stimulant?" We define it as a means of increasing the vitality of some organ, or of the human system in general. Physicians not infrequently prescribe some one of the alcohol-containing liquids which we have mentioned before, for the purpose of invigorating some sluggish organ, such as the stomach or heart of a sick or convalescent person; writers sometimes avail themselves of the "stimulating" effect of a little wine, to accelerate the action of their brain; men

about to expose themselves to the dangers of a perilous journey, or to severe inclemency of the weather, provide themselves frequently with wine or brandy to guard against loss of heat or against other privations.

A healthy, vigorous person requires no artificial stimulus to carry on the regular functions of his system; consequently he needs no stimulating drinks. This does not mean, however, that a small quantity of alcohol greatly diluted with water, such as beer or light wine, taken in small quantities and only infrequently, perhaps once or twice a day, at meal times, will produce a great deal of harm, provided the system is used to it, and readily assimilates and tolerates it. But there certainly exists no sound reason why young persons should use stimulants.

Large doses of alcoholic liquids produce intoxication and *delirium tremens*. The brain is over-stimulated; the reasoning faculties are in disorder; the liver, heart and connective tissues accumulate fat; the channels of nutrition have become impaired, and the whole system has degenerated. When a person has sunk to this lower stage he is said to have *delirium tremens*, which is usually the result of continued intoxication.

1. *Special Effects:*—1. *On the Heart.*—The reason why small quantities of alcohol which are greatly diluted with water stimulate the system, is due to the fact that the alcohol enters the circulation, permeates the body and is burnt up or oxidized within the system, yielding, as a result of this combustion, heat and vital force to the tissues of the body. Since, then, the circu-

lation is stimulated, it follows that the action of the heart is invigorated; the structural part of this organ, however, suffers no change. Larger doses of "stimulants," however, exert a depressing influence upon the heart, rendering it flabby, dilated, and sometimes fatty, so as to reduce its action; they lower the temperature of the body and generally retard the action of the cells. In the language of a medical author —

"The agreeable excitement at first caused by such "doses of alcohol is succeeded by a reaction, char-"acterized by lassitude and drowsiness, the latter "condition usually lasting longer than the previous "one of exhilaration."

In many diseases it is desirable to animate the circulatory system to greater action; this is especially the case with fever patients; they can stand considerable quantities of alcohol without intoxicating effects; and as alcohol lowers the temperature of the body, the fever-heat is lowered also, owing to the use of alcohol, and thereby improves the condition of the patient.

2. *On the Lungs.* — Persons who are addicted to excessive drinking, and especially those "chronic" drinkers who are predisposed to lung troubles, are liable to pneumonia and to consumption.

3. *On the Stomach.* — The immoderate use of alcohol may produce chronic inflammation, congestion or catarrh of the stomach and the duodenum. The inner coat of the stomach is greatly changed by the excessive use of alcohol, and loses its capacity for secretion and absorption. As a result of this, digestion in the

stomach is impaired and the nutrition of the body weakened.

4. *On the Liver.* — A commonly occurring disease of the liver, known as *cirrhosis* of the liver, in which this organ becomes hardened and shrunk, arises from an abuse of alcoholic drinks, more especially of spirits undiluted with water. Most cases of this kind, when once established, terminate in death.

5. *On the Blood and Blood-vessels.* — Whatever impairs the functions of the stomach is certain also to impair the proper condition of the blood and the nutrition of the body; so that an habitual excess of alcohol cannot but deteriorate the "life-giving" liquid. A too frequent use of alcohol tends to change the coats of the blood vessels. Both changes combined — that of the blood and the vessels that circulate it through the body — together with the injurious influence which large doses of alcohol have upon the nerves, have a baneful effect upon the entire system.

6. *On the Brain and Nervous System.* — A large amount of alcohol acts on the nerves and nerve centers as a poison. In the latter stage of drunkenness or debauch it may cause insensibility to such a degree as to produce death. We quote from an expert writer on the subject: "In slight cases of intoxication prolonged drowsiness may be the chief symptom; but in the more severe forms the patient is quite insensible; the power of motion is in complete abeyance; the breathing is loud and deep; the face is usually pale; the pupils are generally dilated; the pulse is slow and

labored; the skin feels cold and clammy; the temperature is low."

Effects of Excessive Use of Alcohol: — (1) *Intoxication.* — The ordinary manifestations of intoxication are too well known to require description. Headache, vertigo, vomiting, coated tongue, staggering walk, disordered vision, loss of appetite, increased thirst, and general lassitude or depression; all these phenomena, or any of them, are the ordinary results of intoxication. If made a habitual occurrence, intoxication passes into what is known as "chronic alcoholism," where those symptoms are greatly intensified, and give rise to muscular tremors, loss of sleep, noises in the ears, dull headaches, foul breath, redness around nose and mouth, dyspepsia, fatty heart, impaired mental condition and general weakness of body and mind.

(2) *Delirium Tremens.* — Chronic drinking may be followed by *delirium tremens*, which is a worse form of "chronic alcoholism," although it may be produced by other causes as well. Its symptoms vary, but as a rule are described as follows: "Inability to take food; marked anxiety and restlessness; tremor of the voluntary muscles; furred and tremulous tongue; cool skin, which is frequently bathed in perspiration; cold hands and feet, and a soft, weak pulse. There is complete insomnia, or short periods of sleep are interrupted by terrifying dreams, and the patient's nights are tormented with visions of horrid insects,

reptiles and other objects pursuing him and eluding his attempts to escape from them or to seize them. His mental impairments increase, and attempts at suicide are common. In this stage a prolonged sleep may occur, and the disease thus terminate. If it continues, the strength fails, the pulse diminishes, the tremor increases, the tongue gets dry and brown in the center, the patient talks incessantly and picks at the bedclothes and death is ushered in by a delusive calm, or takes place in a paroxysm of violence."

(3) *Alcoholic Insanity.* — This species of insanity is a result of alcoholic poisoning; it occurs when a person has inherited a strong tendency to mental disturbance and uses alcohol to excess. Not infrequently this results in a wild delirium called *mania a potu*, during which attempts to commit suicide are often made; or in a melancholical state of mind, which leads to the same suicidal disposition. If sleeplessness, mental depression and a general loss of nervous power associate themselves with those symptoms, this kind of insanity becomes chronic, and may cause paralysis, permanent insanity and death.

STIMULANTS.

Wine is the fermented juice of the grape. One thousand parts of it contain, as a rule, about 900 parts of water, 80 parts of alcohol, and 20 parts of various bodies, such as acids and ethers.

Wines containing a large portion of carbonic acid

gas are called "sparkling" wines; such as contain a great deal of "acid" are called "sour" wines; those containing much free sugar, "sweet" wines, and those containing a large quantity of alcohol, "strong" or "heavy" wines.

Red wines contain from about 10 to 15 per cent of alcohol, which means that 100 volumes of such wines contain from 10 to 15 like volumes of alcohol. White wines contain less.

Rum is the product of the distillation of fermented sugar cane.

Brandy or *Cognac* is a result of the distillation of strong wines.

Arac is obtained by distilling rice or palm juice.

Whisky is a product of the distillation of wheat, rye or corn.

Liquors, in general, are highly flavored liquids containing a large percentage of alcohol mixed with large quantities of sugar.

Beer contains less alcohol than wine; generally not over five per cent.

Coffee and Tea are mild stimulants, yet they should not be taken in strong doses, nor in large quantities. Their effect seems to be to assist digestion; they are therefore generally taken after meals. But their *intemperate* use causes indigestion, nervousness and other troubles.

Chocolate and Cocoa are not so stimulating as coffee and tea, but are much more nutritive.

NARCOTICS.

Narcotics are remedies which induce sleep or insensibility. The principal narcotics in use are (1) *opium* and *morphium*, or *morphia*, (2) *chloroform*, (3) *sulphuric ether*, (4) *chloral*, (5) *cocoaine*, (6) *bromide of potassium*, (7) *belladonna*, (8) *digitalis*, (9) *alcohol*.

In smaller doses these substances cause sleep; in larger doses, insensibility, which may terminate fatally.

1. *Opium* — Laudanum and morphium — these substances are the most effective and reliable narcotics. Laudanum is a preparation of opium. Morphium or morphia, is the most valuable part of opium; it is the morphium in opium which renders opium effective as a narcotic. This class of narcotics may relieve pain even without causing sleep. Opium is administered especially in typhus fever and other disorders, when delirium and loss of sleep may become dangerous to life. But opium also acts as a drawback, as it tends to disturb the stomach. And the habit of "eating" opium is a terrible calamity.

2. *Chloroform.*—This powerful anæsthetic was first introduced by Simpson, of Boston, 1847. It is a very convenient remedy to annul pain, but a very dangerous one, as some persons are particularly liable to be affected by it in the heart.

3. *Sulphuric Ether.* — This is a colorless liquid, the vapors of which, when inhaled, blunt the senses, especially the sense of pain, so that even severe pains

are no longer felt, and short operations may be performed during the time the inhalation goes on. When the inhaling process ceases, sensibility returns almost immediately. It is a much safer narcotic than opium or chloroform.

4. *Chloral.* — This substance is also liable to affect the heart, and is a valuable remedy for simple sleeplessness.

5. *Cocoaine.* — This is an alkaloid obtained from the leaves of *coca*. This drug has but recently been introduced into medicine, and has become very prominent on account of its being the strongest *local* anæsthetic known; that is, it deadens the sensibility of a single organ without affecting the others; for example, if applied to the eye it produces complete insensibility of the cornea and conjunctiva, which permits operations to be performed on this delicate organ without the aid of chloroform or ether.

Another remarkable property of this substance is its anæsthetic effect upon the mucous membrane. Like all narcotics it should be taken or administered with great caution; and the effects of its abuse are terrible.

6. *Bromide of Potassium* is usually administered to restore brain and nerves from the fatigue produced by overwork. It too, however, has, like all narcotics, its disagreeable features, one of which is its weakening influence on the muscles.

7. *Belladonna*, and 8, *Digitalis.* — Both are remedies for strengthening the heart and the arteries, and preventing too free a flow of blood to the brain.

9. *Alcohol.* — The uses, properties and effects of this liquid as a narcotic have been given.

Tobacco contains a volatile alkaloid called "nicotine" which is very poisonous; a drop or two of this poison would prove fatal. But the cases of "tobacco poisoning" by means of nicotine are very rare. The mischief done by smoking cigarettes or by the excessive use of tobacco is of slow growth and effect, but nevertheless sure. To one not used to smoking, the effects of a small dose of tobacco are well known, viz.: vomiting and vertigo. The effects from an excessive use of it are: A tendency to lower the general health; to decrease the digestive capacity; and to weaken or irritate the nerves and brain. While the *temperate* use of tobacco apparently works no harm in adults, this does not argue that it is beneficial to them; and its use by the young should at all times be condemned, because to them even a mild use of it is hurtful.

QUESTIONS.

A.—STRUCTURE.

LESSON I.—Organic and Inorganic Matter—Animal Structure.

PAGE 9.—

1. How are all objects around us divided?

PAGE 10.—

2. Upon what is this division based?
3. How does inorganic matter differ from organic as to form?
4. How, in respect to coherence?
5. How, as to growth?
6. How, as to composition?

PAGE 12.—

7. How, as to derivation?
8. Give the structure of higher animals.
9. Define "Organisms;" "Function." (In Physiology, the term *Function* means *office*, *work*, or *action;* the last is the preferable.)
10. State the functions of Organisms.

LESSON II.—The Skeleton.

PAGE 13.—

11. What effect has intense heat on bones?
12. How does dilute acid affect bones?
13. Of what substances are bones composed?
14. Give the structure of bones.

PAGE 14—

15. How do bones grow?
16. How is the skeleton divided? What is its number of bones?
17. Describe the three cavities of the skeleton.
18. What forms the trunk of the body?

PAGE 16.—

19. How are the arms attached? and how are the movable joints fastened together?
20. How are bones renewed?

LESSON III.—The Head; Cerebro-Spinal Axis; Teeth.

PAGE 17.—

21. Give princ. parts of the head.

PAGE 18.—

22. What two cavities in the head?
23. What is each a part of?

PAGE 19.—

24. What separate tubes do they help to form?
25. Describe the parts of a tooth?

PAGE 21.—

26. Give number and arrangement of temporary teeth in either jaw.
27. Give the same of permanent teeth in either jaw.
28. What sudden changes are injurious to the teeth; and why?
29. Mention two great functions of bones.
    (1st. Locomotion.
    2d. Protection of softer parts, as e. g., the skull protecting the brain.)
30. How do teeth differ from bones?

LESSON V.—The Trunk.

PAGE 24.—

31. Describe the spinal column.
32. What are vertebræ?
33. How are the lungs protected from above, and by what are they encircled?

PAGE 25.—

34. Describe a vertebra.

PAGE 26.—

35. Give three functions of the spinal column.
36. How many ribs are fastened to the sternum; and why do the other ribs not reach it?
37. What lies between each pair of vertebræ?
38. What two offices have these cartilages?
39. How is the variation in the length of the human body explained?
40. How is the pelvis formed?

LESSON VI.—The Limbs.

PAGE 27.—

41. What similarity in the bones of the upper and lower limbs?
42. Describe the hand.

PAGE 28.—

43. Describe the foot.
44. What supports the body when erect?
45. State the purpose of the ball-and-socket joint.
46. Where is this joint found?
47. What is the hinge-joint?
48. How many bones in the foot?
49. Give the object of the arch of the foot?
50. State the chief advantages of the human hand.

LESSON VII. — Cartilages — The Larynx.

PAGE 30.—

51. Give three samples of cartilage?
52. How does cartilage differ from bone?
53. Give four uses of cartilage?

PAGE 31.—

54. What, and where, is the glottis?
55. What is the epiglottis?
56. Bound the larynx.
57. Describe the trachea.
58. Describe the bronchi and bronchial tubes.
59. Describe contents of the larynx.
60. How is sound produced in the larynx?

LESSON IX.—Muscles; Fat.

PAGE 35.—

61. What happens when the forearm is bent up?
62. Describe a muscle.
63. Why are muscles generally called the organs of motion?

PAGE 36.—

64. What is the first property of muscles?
65. What the second?
66. Explain *rigor mortis*.
67. How are voluntary muscles distinguished from involuntary?
68. Give two instances of each class.
69. Which class is uncontrolled by the will?

PAGE 37.—

70. What are the chief uses of fat?

LESSON X.—Muscles Motor Agents—Walking.

PAGE 38.—

71. Show why the arm is considered a lever.
72. To what does the arm owe its variety of motions?
73. By what are those motions exerted?

PAGE 39.—

74. Explain why 100 pounds of effort is required to balance 5 pounds at the free end of the arm stretched out horizontally.

PAGE 40.—

75. In what three forms do we regain much of the muscular force which is apparently lost?

76. How do muscles generally terminate?
77. Decide the first step in the act of walking.
78. Describe the second step.
79. Describe the third step.
80. Describe the fourth step.

LESSON XI. — MUSCLES (CONTINUED)—WORK OF MUSCLES —LEAPING.

PAGE 42.—
81. Explain the fatigue in standing erect long.
82. What are the functions ot connective tissue?

PAGE 44.—
83. Why are the muscles of the head and trunk less substantial?
84. Where is the helmet?
85. Give the number of external muscles.
86. What two motions constitute a leap?

PAGE 46.—
87. How is it that a person in leaping exerts a muscular force of twice his weight into the vertical height?

PAGE 47.—
88. In what way is the mechanical power of the body used to best advantage?
89. How far may we exhaust our forces?
90. What limits should be observed?

LESSON XIII.—SKIN—HAIR AND NAILS—EXCRETION OF SKIN.

PAGE 51.—
91. How is glue produced from skin?
92. Describe the parts of the skin.
93. Describe the epidermis.
94. What are its main functions?
95. What are the main functions of the dermis?

PAGE 52.—
96. Describe the dermis.
97. State the general properties of the skin, and give their uses.
98. Describe the hair and nails.
99. Describe the two excretions of the skin.

PAGE 53.—
100. What does the quantity of water lost by transpiration depend upon?

B.—NUTRITION.

LESSON XIV.—THE BLOOD.

PAGE 54.—
101. Describe the clot.
102. What is the name and the color of the liquid?
103. What is the composition of blood?

PAGE 55.—
104. Give the temperature and specific gravity of the blood.
105. What is the quantity of blood in the body?
106. What does the health of the blood depend upon?
107. Describe the red corpuscles.

PAGE 56.—
108. Describe the white corpuscles.
109. What gases does the blood contain?

PAGE 57.—
110. Give the uses of the blood.

LESSON XV.—THE CIRCULATION. I.

PAGE 58.—
111. How large is the heart?
112. How is it that the blood leaves the heart and returns to the heart again?

PAGE 59.—
113. Describe the divisions of the heart.
114. Describe the communication between auricle and ventricle?

PAGE 60.—
115. Give the course of the blood from the heart, and back again to its starting place.

116. Which artery carries venous blood? With what part of the heart is it connected?

117. Where is the blood rendered impure, and to which division of the heart does the impure blood flow?

PAGE 61.—

118. Mention several helpers which assist the action of the heart.

119. State the functions of each subdivision of the heart.

120. Compare these functions with one another.

LESSON XVI.—THE CIRCULATION. II.

PAGE 62.—

121. How may the movements of the heart be examined?

122. What movements form a pulsation?

123. Define systole and diastole. What is their ratio of time?

PAGE 63.—

124. What is it that prevents the blood, as it leaves the heart, from returning at once into the veins?

125. Describe the auricular systole.

126. Explain the ventricular systole.

PAGE 64.—

127. What is the course of the blood on leaving the ventricles?

PAGE 65.—

128. What two effects has the pressure of the three ounces of blood passing into the arteries after each ventricular systole?

PAGE 66.—

129. What is the pulse? Where may it be felt? Why are the capillaries pulseless?

PAGE 67, 68.—

130. Give the use of the arteries? And state two reasons why compression of veins does not check the circulation.

LESSON XVIII.—THE LUNGS.

PAGE 74.—

131. Define arterial and venous blood. How do they differ from each other?

132. How, and where, is venous blood converted into arterial?

PAGE 75.—

133. Locate and describe the lungs.

134. Give the structure of the trachea, bronchial tubes and the finer tubes.

135. How many lobes in each lung? What is a lobule?

136. What becomes of the finer bronchial tubes?

137. Describe the air-cells and their contents.

PAGE 77.—

138. What is the purpose of the capillaries of the lungs, and how is it accomplished?

139. What does venous blood gain and lose in the lungs? By what means is its purification effected?

PAGE 78.—

140. What is accomplished by inspiration and expiration? What are the most powerful aids in this process.

LESSON XIX.—RESPIRATION.

PAGE 79.—

141. Describe the process of inspiration.

142. Describe expiration.

143. Explain the widening and lengthening of the chest during ordinary inspiration. What are the helps in very deep inspiration?

PAGE 81.—

144. What rhythm is observable in inspiration, and to what is it similar?

145. Give the points in which inspired air differs from expired.

146. Explain the absorption of oxygen by venous blood.

147. What does the oxygen combine with, and what becomes of this combination finally?

PAGE 81.—

148. Why is fresh air necessary, and why ventilation? How does a lack of either shorten life?

PAGE 82.—

149. Explain coughing, sneezing and sighing; also, laughing, sobbing and snoring.

150. Compare the lungs with the heart, giving three points in common and three points of difference.

LESSON XXI.—AIR AND ITS RELATION TO THE BODY. I.

PAGE 87.—

151. Explain the requirement of the body in regard to vital heat.

152. What penalty attaches to the decrease of the normal temperature? What to the increase of the normal temperature?

PAGE 88.—

153. In what ways do we experience losses of heat?

154. Define conduction of heat.

PAGE 89.—

155. Show that water conducts heat better than air.

PAGE 90.—

156. Define radiation of heat. State how a person may expose himself to partial radiation, and what the effects may be.

157. Explain the feeling of cold in windy weather.

158. In what way are bodies affected by conduction and radiation of heat?

PAGE 91.—

159. What explains the loss of heat by evaporation?

160. To what are the injurious effects of wet feet ascribed? How should we guard against cold?

LESSON XXII.—AIR AND ITS RELATION TO THE BODY. II.

PAGE 92.—

161. Describe the functions of our garments.

162. Why is flannel a healthier material than india-rubber?

PAGE 93.—

163. What is the first object of clothing? What the second?

164. Give the characteristics of linen. Why is it to be avoided next to the skin?

PAGE 94.—

165. How does cotton differ from linen?

166. Give the characteristics of woollens. What makes woollen goods valuable as clothing material?

PAGE 95.—

167. Explain why the bed should be warmer than the clothing.

PAGE 96.—

168. State why moist walls are unhealthy. How is their moisture removed best?

169. What does the purity of air depend on? What causes the impurity of air?

PAGE 97.—

170. Distinguish between ventilation and draught. What does ventilation depend on?

LESSON XXIV.—FOOD.

PAGE 101.—

171. What are the principal elements composing the human body?

PAGE 102.—

172. What are the sources of loss to the body?

173. Illustrate this by a man in a glass house.

PAGE 103.—

174. Define food.

175. How are the materials which constitute food divided?

176. What mixture of these divisions is essential to our well-being?

PAGE 104.—

177. Mention two substances that are nutritious but not digestible.

178. Why are many tasteless substances not nutritious? How may they be rendered nutritious.

179. State the purpose of cooking our food.

180. What sensations remind us of the necessity of taking food? What is meant by oxygen-starvation?

SOLID AND LIQUID FOOD

(181.—Fine Print—State the advantages of beef.

182. How does veal compare with beef?

183. How does mutton compare with beef?

184. What are the advantages and disadvantages of pork?

185. What part should fish play in meals?

186. Give the object of eating butter.

PAGE 105.—

187. State the excellencies of wheat.

188. How does the potato compare with bread?

189. Which is, after all, the most important of all foods, and why? What constitutes impure water?

190. What is remarkable about milk? Why are coffee and tea highly valued?)

LESSON XXV.—DIGESTION. I.

PAGE 106.—

191. Whence do plants derive their food?

192. What do animals generally feed on? What great distinction between animals and plants respecting their food?

193. Describe the changes wrought upon the food in the body.

PAGE 107.—

194. Through what channel does food pass into the blood?

195. What is the daily quantity of solid food of a man?

196. What two important additions should be made to this?

197. When does digestion commence?

198. In what consists the first part of digestion?

199. What purpose do the teeth in fishes subserve?

PAGE 108.—

200. Describe the characteristic teeth of the herbivores.

201. Describe teeth of carnivores.

202. What significant arrangement in the human teeth?

203. What is the function of the tongue in digestion?

204. What organs combine to break down the food?

205. Why is it broken down?

206. Why is rapid eating injurious?

PAGE 109.—

207. Describe the second part of the digestive process.

208. State the function of the saliva?

209. When does deglutition take place, and how is it effected?

210. Why may a starving sheep be rightly said to be carnivorous. (See pages 102 and 119.)

LESSON XXVI.—DIGESTION. II.

PAGE 110.—

211. Describe the stomach. What name is given to its two openings, and where are they situated?

PAGE 111.—

212. In what way is the food in the stomach reduced to chyme, and what fluid assists in this operation?

213. Which kind of muscles perform mechanical labor in the stomach?

214. Why cannot the stomach crush an entire grape?

215. State the chief functions of the stomach.
216. What action is temporarily suspended in the stomach?
217. Give the conditions favorable to stomach-digestion.
218. Why may ice-water taken during a meal prove injurious?
219. Give the desirable length of the interval between two consecutive meals.
220. State the process undergone by the food between the mouth and the pylorus.

LESSON XXVII.–DIGESTION. III.

PAGE 113.—
221. Describe the intestines.
222. How are they divided?
223. State the length of the small intestine, and of the entire alim. canal.
224. Where does the peristaltic motion take place, and what does it consist in?

PAGE 115.—
225. How is the large intestine divided?
226. Describe the position of each part.
227. How is the large intestine readily recognized?
228. How does the motion of the large intestine differ from that of the small?
229. Mention all the digestive fluids.

PAGE 116.—
230. What is the purpose of the mucous substance secreted by the stomach?
231. Describe the other liquid secreted by the stomach.
232. What action has this liquid upon fatty substances?
233. Explain the pernicious effect upon the stomach of immoderate quantities of alcohol.
234. What two actions convert the food into chyme?
235. What becomes of the chyme after leaving the stomach?
236. Where does the food undergo its most important change?
237. Describe the liver.
238. What are the functions of the liver?
239. Where does the bile accumulate, and whither does it flow?

PAGE 117.—
240. Why must the bile be conducted out of the system?
241. What does bile produce when in the blood?
242. What does bile produce when thrown into the stomach?
243. What name has the chyme after its union with bile?
244. Give the remaining two actions of the bile.
245. State the composition of the chyme when leaving the stomach.

PAGE 118.—
246. What distinguishes the pancreatic juice?
247. Describe the pancreas, and the peculiarity it has in common with the salivary glands of the mouth.
248. What is the office of the intestinal juice? Where is it secreted?
249. What is the estimated quantity of the five digestive liquids a day? What of the gastric juice alone?
250. Describe the combined action of those five liquids.

LESSON XXVIII–ASSIMILATION.

PAGE 119.—
251. Explain the interdependency of life and death in the organism.

PAGE 120.—
252. How is digested aliment converted into blood so as to be distributed over the entire body?
253. Describe the twofold object of absorption.

PAGE 122.—

254. Describe blood-vessels or capillaries (Fig. 26). Describe the lacteals (Fig. 27).

255. Describe the absorption of the chyle by blood-vessels.

256. Describe the absorption by the lacteals.

257. Explain the absorption of chyle by a villus.

PAGE 123.—

258. Describe the lymphatic glands.

PAGE 124.—

259. Describe the position aud action of the thoracic duct.

260. Trace the further progress of the chyle.

C.—INNERVATION.

LESSON XXX.—The Nervous System. I.

PAGE 130.—

261. Give the first two functions of the nervous system, demonstrating each.

PAGE 131.—

262. Give the third, fourth and fifth functions, demonstrating each;

263. Give sixth and seventh functions, and demonstrate each.

PAGE 132.—

264. How is the nervous system divided and subdivided?

PAGE 133.—

265. Describe the brain.

PAGE 134.—

266. Describe the cerebrum and cerebellum.

267. Describe the spinal cord.

268. Where do the cerebro-spinal nerves originate? What is their form?

269. Describe nervous fibres. Where do they originate?

270. What do nervous fibres form at their termination?

271. What is the size of those nervous fibres, and where are they smallest?

PAGE 135.—

272. What does the sympathetic system consist of?

273. Where is it situated, and how is it connected?

274. What course is pursued by its nerves?

PAGE 136.—

275. Mention the two substances composing the nervous system.

276. Where is the white substance within the gray, and where the gray within the white?

277. Of which substance are the nervous fibres and tubes? Of which the cells?

278. Which substance forms the central organ of the nervous system?

279. What function has the gray substance? What function the white?

280. To what may both materials be compared?

LESSON XXXI.—The Nervous System. II.

PAGE 137.—

281. Explain the reason for the convolutions in the brain.

PAGE 138.—

282. What seems to be the function of the cerebral hemispheres? and what are the reasons for believing this?

PAGE 139.—

283. State the function of the medulla oblongata.

284. In what respect is the medulla obl. specially distinct from the brain and the spinal cord?

285. Give the functions of the spinal cord.

PAGE 140.—

286. Describe the functions of the sympathetic system.

287. Explain the two special functions of the nerves.

288. Demonstrate the existence of motor nerves.

PAGE 141.—

289. Demonstrate the existence of sensory nerves.
290. What are the nerves of the spinal cord endowed with?

LESSON XXXIII.—THE SENSES.

PAGE 144.—

291. Define sensory organs.
292. What is sensation? Show by an example.

PAGE 145.—

293. Distinguish between objective and subjective sensations.
294. Explain in what manner the sense of sight is produced.
295. How are sensations generally produced, and what becomes of them?

TOUCH.

PAGE 146.—

296. Give the common sensations excited by the sense of touch.
297. In what does its distinct structure exist?
298. Show by facts that an excess of heat or cold produces like impressions.

PAGE 147.—

299. How far do the nerves retain their sensibility to touch?
300. State why this sense seems capable of great improvement.

LESSON XXXIV.—TASTE.

PAGE 148.—

301. Give the most frequent sensations excited by the sense of taste.
302. In what does the distinct structure of this sense consist?
303. What tends greatly to modify the sense of taste? And what is remarkable about the tongue?
304. How can it be proved that this sense is largely connected with other senses?

SMELL.

PAGE 149.—

305. Give the principal sensations produced by the sense of smell.
306. Describe its structure.
307. How are the nasal chambers protected from dryness?
308. What form must all matter have in order to impress itself. upon the olfactory nerves?
309. How does a dog obtain the scent of an object?
310. State what connection there is, if any, between bad odors and their supposed effects?

LESSON XXXV.—SIGHT. I.

PAGE 150.—

311. State the principal sensations excited by the sense of sight.
312. Describe the structure of this sense.
313. What does the eye-ball owe to the membrane which covers it, and of what does the eye-ball consist?
314. Describe the choroid.

PAGE 151.—

315. Describe the iris.

PAGE 152.—

316. Desc·ibe the retina.
317. How may the blind spot in the eye be readily detected?
318. What do we experience when the retina is in a state of utter rest?

PAGE 153.—

319. Describe the optical apparatus of the eye.
320. What functions have the eye-brows and eye-lids? And how is the mobility of the eye-ball effected?

LESSON XXXVI.—SIGHT. II.

PAGE 154.—

321. Describe a *camera obscura*, and the principle of photography.

322. Show that the eye may be compared to a camera obscura.

PAGE 155.—

323. What is the experiment that proves that the eye can adjust itself to different distances.

PAGE 156.—

324. Describe the distance of distinct vision.

325. Explain short-sightedness and long-sightedness, and tell how each may be neutralized.

PAGE 157.—

326. Explain visible direction.

PAGE 158.—

327. What is known regarding the duration of impressions on the retina?

328. What is color-blindness?

329. How may the sensitiveness of the retina be ascertained?

330. Mention two frequent sources of injury to the eye.

LESSON XXXVII.—HEARING.

PAGE 159.—

331. What are the principal sensations derived from the sense of hearing?

PAGE 160.—

332. Give the general structure of this sense.

333. Describe the outer ear.

334. Describe the external tube and the drum of the middle ear.

335. Describe the contents of the drum.

336. What seems to be the function of the eustachian tube?

PAGE 161.—

337. Describe the labyrinth.

PAGE 162.—

338. State how the sensation of sound is produced.

339. Compare the ear with the eye, giving three points in common.
(1. Outer ear and ext. tube—opt. apparatus.
2. Tympanum—retina.
3. Auditory nerve — optic nerve.)

340. Find three points of difference.

LESSON XXXIX.—THE MIND.

PAGE 166.—

341. Describe the two apparatus of life.

PAGE 167.—

342. State the difference between the higher animals and man, as regards domestication, education and the consciousness of the infinite.

343. What specially characterizes the human species, at least the higher types of man?

PAGE 168.—

344. Give proofs of the dependence of the mind on the body.

345. Give proofs of the dependence of the body on the mind.

346. When is a person said to be attentive?

PAGE 169.—

347. Demonstrate, by examples, that there is an inward and an outward attention.

348. Define sensation and perception.

PAGE 170.—

349. Define idea.

PAGE 171.—

350. Define physiology.

LESSON XL.—ALCOHOL—STIMULANTS—NARCOTICS.

PAGE 172.—

351. State prop. and uses of alcohol.

352. Give general effects of stimulants.

353. What is a stimulant?

354. Give effects of small and large doses of alcohol or stimulants.

355. Mention three special effects of alcohol.

356. Describe 3 effects of the excessive use of alcohol.

357. State 5 important narcotics and their uses and effects.

358. Give effect of excessive use of tobacco.

359. State effect and use of coffee and tea.

GLOSSARY,

CONTAINING THE ANATOMICAL AND PHYSIOLOGICAL MEANING OF CERTAIN TERMS.

Ab-do'men. The largest cavity of the body; below the diaphragm and above the pelvis, containing the stomach, intestines, liver, spleen, etc.

Ac'id. A substance generally sour to the taste, which changes vegetable blue colors to red, and combines with bases to form salts.

Adipose'. Fat, or fatty.

Albu'men. A substance like the white of an egg, coagulating by heat.

Alcohol. A result of the formation of sugar.

Al'i-ment. Nourishment; food.

Al-i-ment'a-ry Ca-nal. A tube passing through the body, beginning with the mouth, piercing the diaphragm, and terminating with the rectum, by which nourishment is taken into the body, digested, and indigestibles excreted.

Aor'ta. The great artery arising from the upper and the back part of the left ventricle of the heart; the common trunk of the arteries of the body.

Appara'tus (Physiol.) A system of organs concerned in some special function of the animal body.

Arac. Product of the distillation of rice or palm-juice.

Ar'tery. Any branch of the aorta conveying blood in the direction from the heart to all parts of the body.

As-sim-i-la'tion. The conversion of food into the substance of organized beings.

Au'ricle. The external ear. Hence one of the two venous chambers of the heart, resembling the external ear.

Beer. A fermented liquid made from any malted grain, with the addition of hops or other substances.

Bi'ceps. Two-headed. A muscle attached to the shoulder-bone, connecting it with one of the bones of the fore-arm.

Bicus'pid. A molar tooth having two points.

Brandy. A result of the distillation of strong wines.

Bronch'us. The windpipe, or trachea. The *bronchi*, or *bronchia*, now mean the two tubes which arise from the bifurcation of the trachea, and carry air into the lungs.

Cognac. A result of the distillation of strong wines.

Cam'era–obscu'ra. An instrument used in a darkened room to throw images of external objects upon a surface.

Ca-nine'. Applied to teeth, it means the pointed tooth next to the incisor. It is often quite long.

Cap'-il-la-ries. A net-work of minute blood-vessels, connecting the termination of the arteries with the termination of the veins.

Car'di-ac. From the Greek *kardia*, the heart.

Carniv'orous. Flesh-eating. *Carnivore*, a carnivorous animal.

Car'ti-lage, or gristle. A dense, firm substance of less hard tissue than bones.

Cell. A small, distinct, spheroidal mass of protoplasm or living material.

Cer-e-bel'lum. The little brain, beneath the cerebrum.

Cer'e-brum. The brain proper, occupying the entire upper portion of the skull.

Cho'roid. A coat containing a great many blood-vessels, lining the interior surface of the sclerotic coat of the eye.

Chyle. A milky fluid formed in the process of digestion by the action of the pancreatic juice and the bile on the chyme in the duodenum.

Chyme. A pulp formed by the action of the stomach on the food.

Cil'i-ary Processes. The minute radiating ridges formed around the iris by the anterior portion of the choroid.

Clav'i-cle. The collar bone.

Coch'lea. A cavity of the ear resembling a spiral shell.

Cohe'rence. The act or state of cohering.

Co'lon. That portion of the large intestine extending from the cæcum to the rectum.

Connec'tive tissue. The connecting medium by which the different parts of the body are held together. It passes from the dermis between all the other organs, ensheathing the muscles, coating the bones and cartilages, and ultimately entering into the mucuous membranes.

Contrac'tile. Having the power of contraction.

Corpus'cle. Minute body or particle of matter.

Cu'ti-cle. The superficial layer of the skin. The same as *epidermis.*

Cutis. The deeper portion of the skin. The same as *dermis.*

Degluti'tion. The act, or power, of swallowing food.

Delirium Tremens. Usually the result of continuous intoxication.

Dentine. The principal constituent of a tooth.

Deriva'tion. Transmission of anything from its source.

Dermis. The same as *cutis.* (See this.)

Diaphragm. The muscular partition separating the chest from the abdomen, and assisting respiration.

Dias'tole. A dilatation of the heart and arteries; opposed to *systole.*

Digestibility. The quality of being digestible.

Dilatation. Expansion.

Duodenum. The first of the small intestines; is about as long as the breadth of twelve fingers.

Enam'el. The hard exterior surface of the teeth.

Epidermis. The same as cuticle. (See this.)

Epiglot'tis. A cover on the aperture of the windpipe.

Eu-sta'chi-an Tube. A tube extending from the inner side of the tympanum, opening at the back of the nostrils.

Fetor. A strong, offensive smell.

Fi'brine or *fibrin.* A white, tough, fibrous substance, obtained from coagulated blood.

Func'tion. Performance, office work, action. (See Ques. 9.)

Gan'gli-on, pl. *ganglia.* A mass of nerve-cells, forming a center from which nervous fibres radiate.

Gas'tric. Belonging to the stomach.

Glot'tis. Aperture at the top of the larynx.

Hem'or-rhage. Loss of blood; bleeding.

Herbiv'orous. Feeding of plants. *Herbivore*, herb-eating animal.

Hy'gi-ene. The knowledge of the preservation of health.

Il'eo-jeju'num. The part of the small intestine immediately succeeding the duodenum.

Incis'ors. The four front teeth of both jaws.

Innervation. The function of the nervous system.

Inorgan'ic. Destitute of organs or animation.

In-sal-i-va'tion. The mixing of food with saliva.

Iris. A membrane with an aperture in the center, stretched vertically across the eye, and separating the anterior from the posterior chamber. It gives the eye its color.

Lab'y-rinth. The internal ear.

Lac'te-al. A lymphatic vessel of the intestinal canal. (See *Lymphatic.*)

Lar'ynx. Cavity at the top of the trachea, the organ of voice.

Lever. A stiff bar or rod, which turns on, or is supported in, a fixed point.

Lig'a-ment. A strong fibrous material, uniting bones or other solid parts together.

Liquors. Highly flavored liquids containing large quantities of alcohol and sugar.

Lymphat'ic. Vessel conveying a colorless, watery fluid, called *lymph*, to the thoracic duct.

Mas-ti-ca'tion. The act of chewing.

Me-dul'la Ob-lon-ga'ta. "The oblong marrow." Portion of the nervous cord within the skull nearest to the spinal cord.

Mem'brane. A thin layer of tissue, serving to separate, cover, or envelop other organs.

Mo'lar. A grinding tooth.

Mo'tor. Giving motion.

Mu'cous Mem'brane, or Mucous Coat. The continuation of the skin, in apertures and interior cavities: that is, the lining of the internal cavities.

Mu'cus. A more or less tenacious fluid.

Narcotics. Remedies inducing sleep or insensibility.

Nutri'tion. The conversion of food into nutriment. Sometimes used to comprise digestion, absorption, respiration, circulation and assimilation.

Œ-soph'a-gus. The tube which extends from the interior portion of the pharynx to the stomach; the gullet.

Organ'ic. Having organs, animation; or, pertaining to organs. Hence, *organism*=an organic being.

Ossifica'tion. The formation of bone.

Pal'ate. The roof of the mouth.

Pancreas, or "*sweet-bread*." A gland of the abdomen, under and behind the stomach, at the right of the spleen.

Pel'vis. Two separate bones to which the legs are attached, and which bound the abdomen below.

Phys-i-ol'o-gy. The science of the functions of animals and vegetables. Human physiology is the science which treats of the functions of the human body and the manner in which they are brought about.

Proc'ess. Eminence of a bone; a portion prolonged beyond others with which it is connected.

Pul'mo-na-ry. Pertaining to or affecting the lungs.

Py-lo'rus. The lower or right orifice of the stomach.

Ret'i-na. A very delicate membrane, lining the hinder two-thirds of the eye-ball. It is the continuation of the optic nerve.

Rhythm. A measure of anything according to the number of regularly occurring impulses.

Rigor Mortis. Stiffness of the entire body after death.

Rum. Product of distillation of fermented sugar cane.

Sa'crum. The triangular bone forming the posterior part of the pelvis, and terminating the vertebral column. It is a union of the 25th, 26th, 27th, 28th and 29th vertibræ into one great bone.

Sa-li'va. A thin watery liquid of the mouth, having the property of converting starch into sugar.

Sapid'ity. The quality of bodies that gives them taste.

Scle-rot'ic. The white of the eye. A tough, firm spheroidal case, the greater part of which is white and opaque.

Se-cre'tion. The separation of substances from the blood of animals, or from the juice of plants.

Sensibil'ity. The power which any tissue of the body has of causing changes inherent or excited on it to be perceived and recognized by the mind.

Se'rum. Watery part of animal fluids, as of blood or milk.

Skel'e-ton. The solid framework of the body of an animal.

Stimulant. Means of increasing the vitality of some organ or of the human system.

Sympathet'ic. A long double series of ganglia connected together by nervous cords.

Sys'to-le. The contraction of the heart — opposed to *diastole.*

Tac'tile. Perceptible to, or susceptible of, touch.

Tem'perature. The amount of heat which a body may communicate to other bodies.

Ten'don. A white cord attached at one end to a bone and at the other end to a muscle; the same as *sinew.*

Tho'rax. The chest; the part of the body between the neck and the abdomen.

Thorac'ic. Pertaining to the thorax.

Tis'sue. A membranous organization of parts.

Tra'chea, or *Trach'ea.* A tube strengthened by cartilaginous rings extending from the larynx downward along the front part of the thorax, and passing into the thorax where it divides into two branches, a right and a left, called the *bronchi.*

Tym'pa-num, or *Drum.* Cavity of the middle ear, separated from the external ear by the tympanic membrane.

Vein. A vessel to convey venous blood to the heart.

Ven'tricle. Generally applied to the two cavities of the heart which communicate with the auricles. Applied also to other cavities in the body.

Ver'te-bra, pl. *Vertebræ.* One of the bones composing the vertebral column. It consists of a main part, called the body of the vertebra; and of seven projections, called processes.

Vil'li. Soft projections or processes covering certain membranes.

Vit're-ous Humor. The transparent mass which fills the eye behind the crystalline lens.

Wine. Fermented juice of the grape.

Whisky. Product of distilling wheat, rye or corn.

INDEX.